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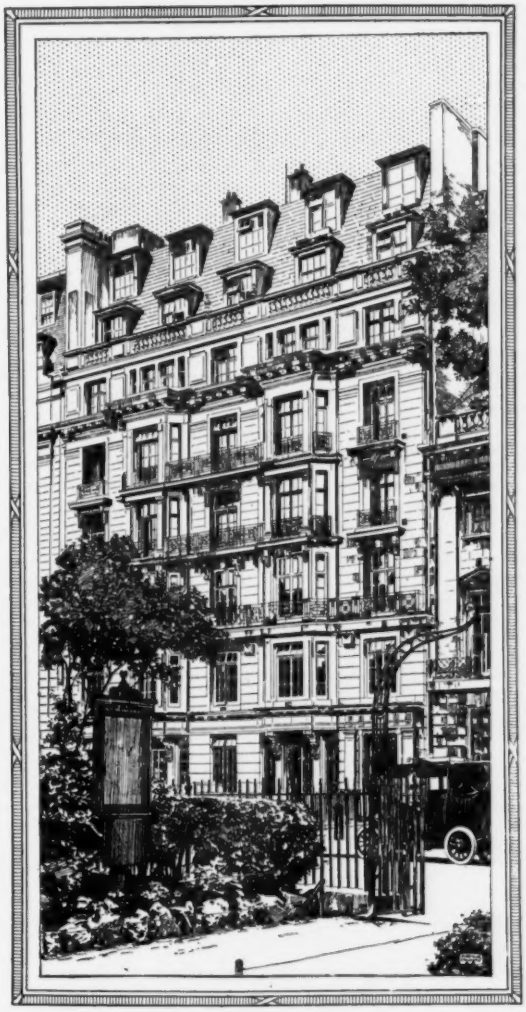

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Main Cables Run on Tower Wall at D.R. Cotton Mills, Rochdale.

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EDITORIAL.

All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2.

REFLECTIONS ON UNEMPLOYMENT.

In the conflict of opinions as to the proper authority to bear the financial burden of unemployment, there is some danger that the fundamental facts of the present situation may be obscured. Those facts seem to us to be that there are one and a half million workpeople out of work, in addition to a very large number on short time, and that for some months to come there is little prospect of any great proportion of these being reabsorbed into industry through the normal revival of trade. If we are right in this analysis of the position —and it would be difficult to find anyone seriously to question it—it is plain that provision to relieve unemployment must be made at once and on a large scale. In one form or another, through whatever public authority, the country has to face, and we believe is prepared to face, considerable expenditure. The most urgent need of the moment is to determine how the money which admittedly has to be spent can be spent to the best advantage.

If we do not propose here to discuss the suggestions which have been made for extended schemes of export credits, it is not because we under-estimate the importance to the country of the restoration of its export trade. Full employment in industry here is unattainable with exports at their present level. But whatever use may be made of export credits, it is clear that in the near future money will have to be spent in other ways as well, either in the payment of doles or on relief work or in some other form. Every thinking man knows that both the dole and conventional relief work are pernicious remedies. But they have the attraction of familiarity ; and so fearful are we all of the imputation that any other method would involve the use of public money in aid of private enterprise, that we slip into acquiescence in what we have long ceased to believe in. Our purpose here is to urge that the times are too critical for the nation to follow the worst course out of timidity when the boldest is the best, and that money should be spent on productive schemes rather than on the digging of reservoirs and the making of parks or on maintenance divorced from work. It is not always realized what the loss to the nation through ordinary relief work is. Take a man earning £4 a week in an engineering shop and transferred through lack of employment to relief work at the same wage. His normal employer has a clear loss, in unabsorbed establishment charges, of £5 a week, on the moderate basis of establishment charges of 125% on labour. On relief work a good tradesman is inefficient and uninterested, and of the £4 a week which he is paid probably not more than £1 on the average has any permanent value. There is therefore a loss to the nation of £8 a week through this one man being turned adrift from his normal employment. An electric power station, on the other hand, or the electrification of a railway absorbs an enormous amount of direct labour per £ expended, and it is an important addition to the wealth and the wealth-producing capacity of the country. An examination of an actual railway electrification scheme, which would cost £6,000,000 and could not fail to produce a very high return on the money spent, shows that when every allowance is made for certain imported materials, such as copper, £4,800,000 out of the total capital cost of six millions would be spent on direct labour in this country. Nearly all the great railway companies have schemes for electrification worked out or in contemplation, but it is unreasonable to expect that the large sums of money required can be raised unless the status of this new money in relation to the present capital of the railways is safeguarded. If the Government would trust the great industries of the country by facilitating the financing of such schemes, a large number of men could be found employment at their own trades, instead of being left to the slow demoralization of the dole or useless relief work.

Mechanical Advantages of Electric Locomotives compared with Steam.

By Sir Vincent Raven, K.B.E., M.Inst.C.E.

[*Through the courtesy of the author and the Institution of Civil Engineers we are enabled to publish the following note which was included in an address given by Sir Vincent Raven, at the* 1921 *Engineering Conference held at the Institution. We are especially glad to do this, because the address by its conciseness and lucidity seems to us a valuable contribution to a subject of great present importance.*]

In a comparison between steam and electric locomotives there are a number of prominent features in both types that are perhaps best expressed by the terms " for and against " or " advantages and disadvantages."

Admittedly the practical experience of locomotive engineers in this country has been almost exclusively confined to the steam locomotive, and for that reason it would probably be well to enumerate in the first instance the mechanical limitations and disadvantages which, every engineer will agree, exist in the steam locomotive and which, it may be argued, are overcome to a very considerable extent by the adoption of the modern and more up-to-date system of electric traction.

The mechanical disadvantages of the steam locomotive may be briefly summarized as follows :—

The locomotive being a complete independent unit, its power cannot be greater than the capacity of its boiler.

To increase the boiler capacity obviously implies increased dimensions and weight, both of which offer grave difficulties in regard to clearances and strengthening of bridge structures.

It is known that on many railways in Britain the limit of weight has been reached, and further development of power is only possible at enormous expense.

The boiler, cylinders, valve-gear, crank-shafts and all reciprocating parts are costly to maintain.

Turntables, fuelling plant and water supply appliances must be provided.

The cab is small and open to the weather, involving discomfort to the locomotive crew.

The locomotive radiates heat and uses coal all the time steam is up, that is, during many hours when it is doing no work, and either standing by or coasting.

The wear and tear of the locomotive on the track is considerably increased by the impossibility of accurately balancing the reciprocating parts.

The case for the electric locomotive may be set out by the brief statement that it is not hampered by any of the above-mentioned objections. In addition, one might point out that it possesses other important qualifications, such as :—

Simplicity of mechanical construction and operation.

Increased power of acceleration.

Higher scheduled speed due to the possibility of heavy short period overloads, resulting in more frequent service and increased use of existing tracks.

Uniform turning effort resulting in better factor of adhesion at starting and on gradients.

Absence of all reciprocating movements and accurate balance of all rotating parts.

Facilities for driving from either end of a locomotive.

Accessibility of mechanical and electrical parts.

Better accommodation for locomotive crew by reason of increased cab area and by closing in and heating the cab.

Possibility of coupling two or more locomotives together under the control of a single driver.

Owing to the limitations of this Note, probably sufficient is here put forward to invite a full and exhaustive discussion, but two special points may be referred to, namely, the fuel economy made possible by the use of electric locomotives, and the cost of maintenance.

Fuel Economy.—The production of energy in a power station rather than on the locomotive leads to a very substantial economy of fuel. On a steam locomotive fitted with all modern improvements, it is not practicable to work at less than about 2¼ lbs. of best quality coal per B.H.P. hour, and very few engines are capable of doing this for any length of time. Taking into account additional fuel required for lighting up, standby losses, periods of uneconomical working and other factors continually met with in practical working, the average consumption is more like 3½ lbs. per B.H.P. hour for passenger engines, and 5 lbs. for goods engines.

On the other hand, with electric locomotives, whether passenger or goods, and with up-to-date power station and sub-station plant, it is possible to reduce the consumption of fuel to 1¾ lbs. per hour, or even less, of low quality coal per B.H.P. produced on the locomotives. In other words, electrification enables the fuel consumption to be reduced to one-half or one-third, the fuel employed being of a quality unsuitable for steam locomotives.

Cost of Maintenance.—Our own experience with regard to the cost of repairs of electric locomotives working between Shildon and Newport shows that this cost is approximately one-third that of maintaining the steam locomotives which worked this traffic previous to 1915.

The difference in America, however, is much greater, as Mr. Armstrong, Chairman of the Electrification Committee of the General Electric Company gives figures showing the cost of repairs per mile of three American railways varying from 6·3 cents to 14·6 cents, as compared with a cost of 60 cents per mile for a 2-8-8-2 Mallet steam engine, which is the class of engine that would have to be used to haul a similar train to that taken by the electric locomotive, the cost of repairs of which is 14·6 cents, or one-fourth that of the steam engine.

A Motor Installation in a Large Textile Factory.

By J. T. Randles, A.M.I.E.E.

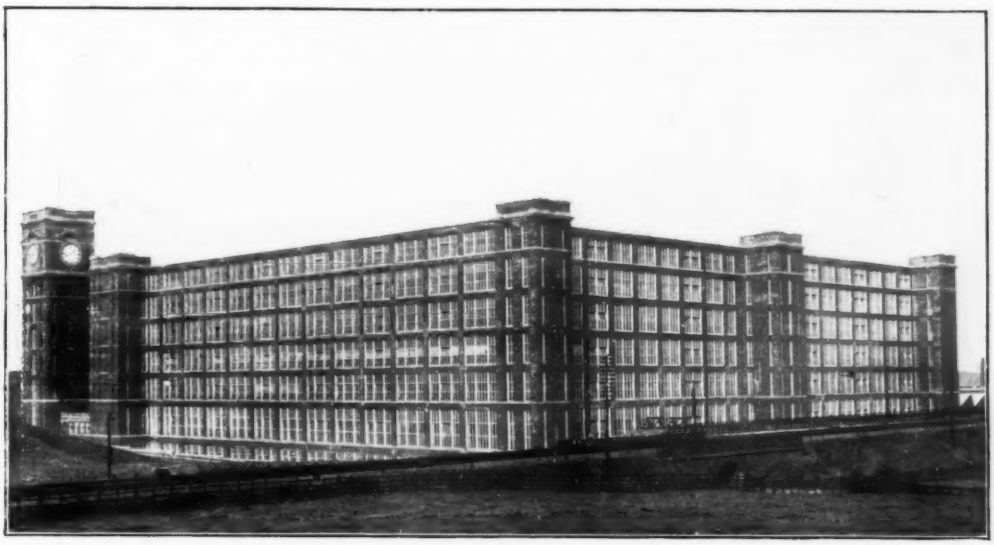


Fig. 1. The New Spinning Mill.

It is proposed in this article to describe briefly the driving equipment in a modern electrically driven cotton mill, the new spinning mill recently built as an extension to the D.R. Cotton Mills, Rochdale.

These mills, consisting of both spinning and weaving sections, were built in 1914 to produce the fabric, etc., used in the manufacture of Dunlop Tyres and during the last two years extensions considerably larger than the original mills have been added to meet the growing requirements of the Company. Power is obtained from the Rochdale Corporation, the transmission pressure being 10,000 volts (3 phase, 50 periods), and two transformer sub-stations, 10,000/400 volts, are provided in suitable positions with relation to the mills, one with an ultimate capacity of some 10,000 KVA., for supplying the spinning sections and the other of rather smaller capacity for the weaving sections. From the low-tension switchboards in these substations three-phase feeder cables run to low-tension distributing switchboards of the ironclad industrial type in the various sections.

The new spinning mill illustrated above is a ring spinning and doubling mill of seven storeys, square in form, covering about three and a quarter acres; the first flat or basement being arranged partly as a store and partly as a blowing room, the second flat as a doubling room, the third, fourth, fifth and sixth flats as carding and spinning rooms and the seventh flat as a finishing room.

Dealing first with the distribution, it was found when designing the driving equipment for this mill that owing to the large power involved (some 9,000 H.P.) the satisfactory installation of the cables would be a very difficult matter unless proper provision was made while the mill was being built; the cable system was therefore planned in detail and all fixings, conduits through walls, etc., built in as the building proceeded. The final running of the cables was thus greatly facilitated, and masons' attendance cutting away and making good reduced to a minimum, frequently a considerable item on an undertaking of such magnitude.

For the main power feeders and distributors

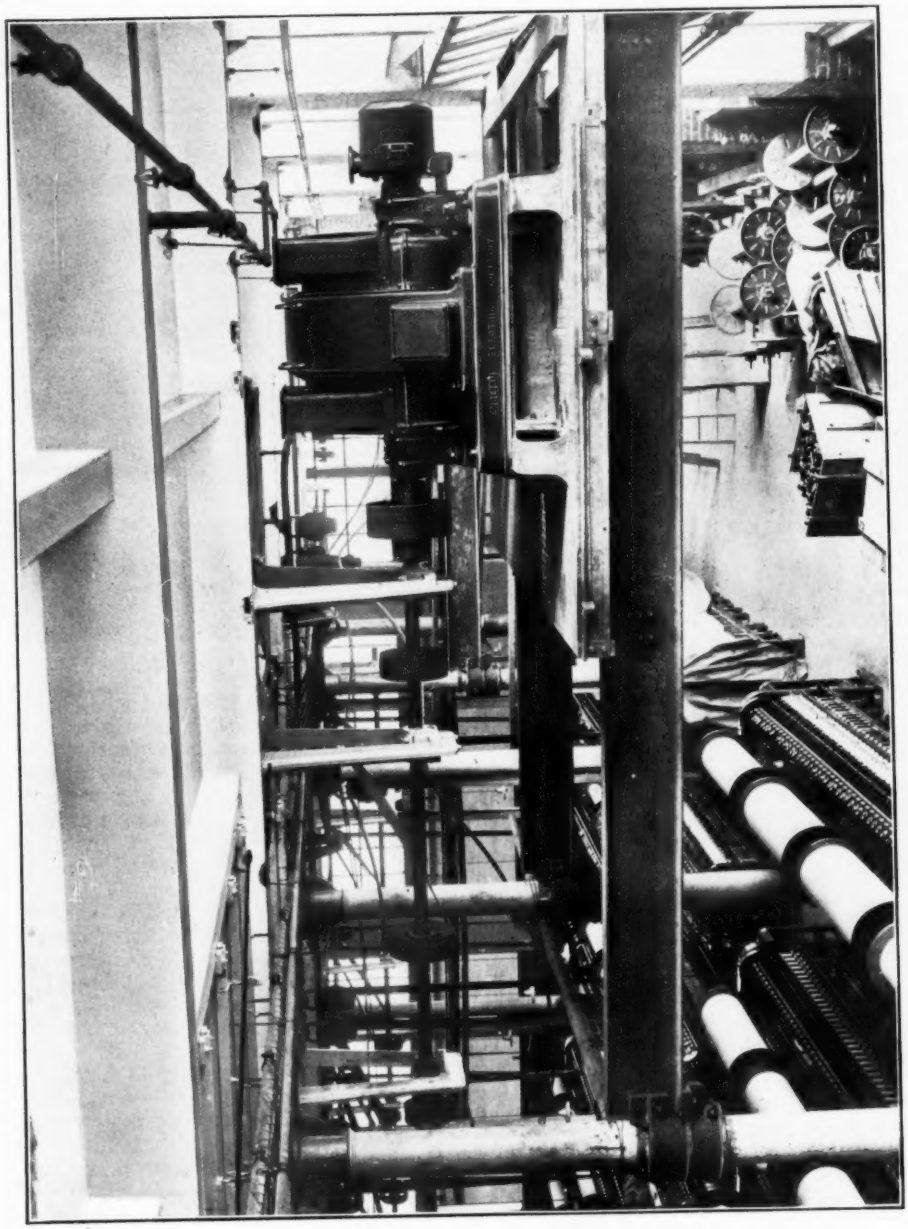


FIG. 2. 250 H.P. DIRECT-COUPLED MOTOR IN DOUBLING ROOMS.

it was found convenient to use only three sizes of cable, ·3 sq. in., ·2 sq. in. and ·1 sq. in., all three-core ; in the case of the feeders three or four ·3 sq. in. cables were run in parallel in preference to using larger sizes, as above this size the permissible current density per sq. in. of area is considerably reduced and the cable becomes very unwieldy from the point of view of installation. Further, this arrangement for use in cotton mills as it is more easily kept clean and free from fluff than a served or braided cable and it is unaffected by the fairly high temperatures sometimes found in textile mills. The cable was manufactured and installed by Messrs. Siemens Brothers & Co., of Woolwich.

The larger of the two substations referred to above abuts on one of the staircase towers of

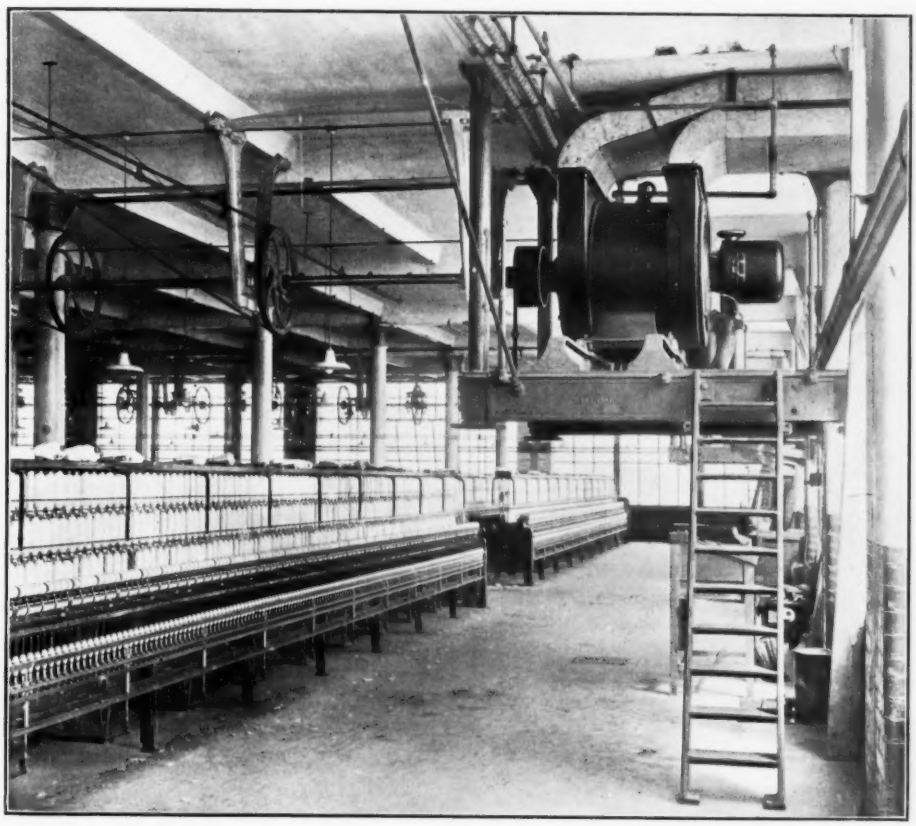


FIG. 3. 150 H.P. MOTOR DRIVING RING FRAME SHAFTS.

permits of any feeder being conveniently duplicated in the future if required. These cables are all paper-insulated, lead-covered and single-wire armoured, and the armouring is galvanized (left bright) and provided with a spiral binder wire to keep it in place during installation. This type of cable is very suitable the mill, and switchrooms for accommodating the distribution switchgear are incorporated in this tower, one switchroom being provided for each flat. One of the walls of the tower is utilized for carrying the main feeder cables from the substation to the various switchrooms, as shown in the frontispiece. As these

cables weigh nearly 30 lbs. per yard run each, it was necessary to provide secure means for supporting them in the vertical position, the vertical run in the case of the seventh flat being approximately 30 yds., and to attain this a horizontal row of cast-iron bricks provided with T slots was built into the wall at suitable intervals, to which the cables were fixed by cast-iron clips. This construction, which has proved very satisfactory, is clearly shown in the illustration.

The distributor cables connect the various motors or groups of motors in the flats with the distribution switchgear in the switchrooms. Provision was made for installing these cables at the time the mill was built, "Rigifix" fittings, to which the cable cleats are bolted, being incorporated as required in the reinforced concrete floors of the switchrooms and under the staircases to the flats, while cast-iron conduits were provided for the passage of the cables through the mill walls where necessary. In the mill itself the cables are run on the ceilings of the flats, light beams bridging the lower flanges of the floor girders being provided to carry the cable cleats. Figure 4 illustrates this method of supporting cable runs, which has many advantages over the ordinary method of cutting holes and grouting in fixing bolts when the installation is a large one. A separate circuit is provided for every motor of 70 B.H.P. and upwards, corresponding to a line current of approximately 100 amps. or more. In the case of the 50 H.P. motors referred to below, a group of three motors is supplied from one distributor, the motors being connected to the cable through link boxes; distribution boxes fitted with fuses are only used for supplying groups of the smallest motors, 20 H.P. and less.

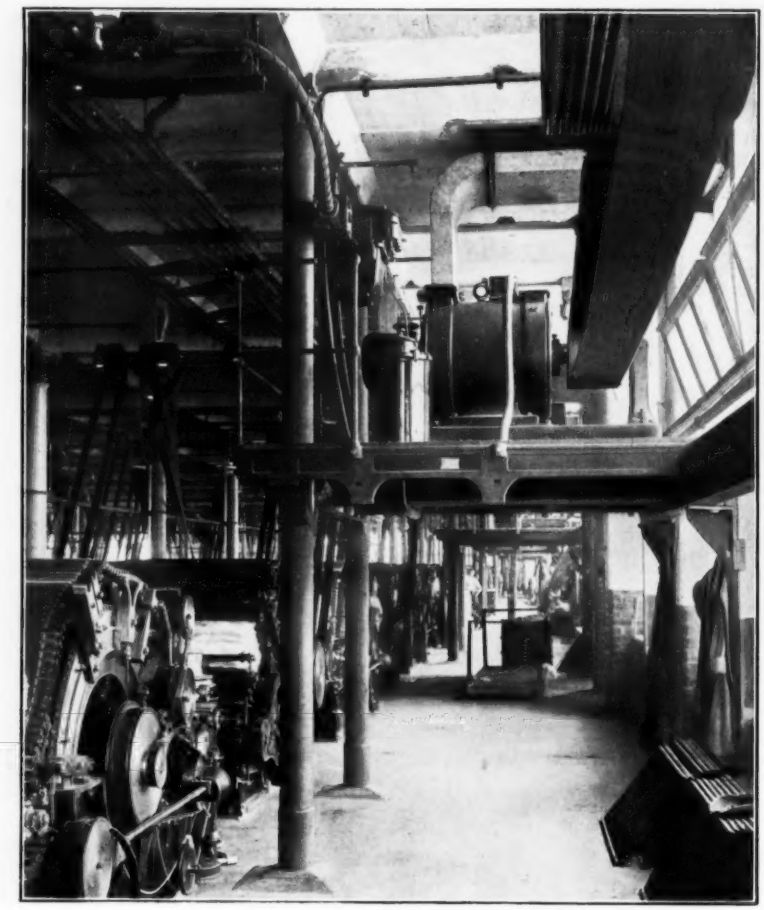


FIG. 4. 50 H.P. MOTOR DRIVING CARD SHAFTS.

The motors installed in all the rooms except the basement are of the pipe-ventilated slip-ring type, fitted with brush lifting and short circuiting gear, the drives being

arranged on the group system. Broadly speaking there are two systems which may be adopted when installing motors for group driving in a cotton mill; that of placing the motors in a separate motor tower or corridor, and that of placing the motors on suitable elevated platforms inside the mill rooms. In the case now being considered, owing to the size of the mill and consequently the number of shafts to be driven in each room, the former system was not suitable. It was found possible in adopting the latter system, however, to place all the motors adjacent to the walls of the mill, thus allowing the use of pipe-ventilated motors provided with ducts to draw cooling air from outside; this arrangement effectively avoids the disadvantages which follow from placing open or protected-type motors in an atmosphere containing cotton fibre or fluff.

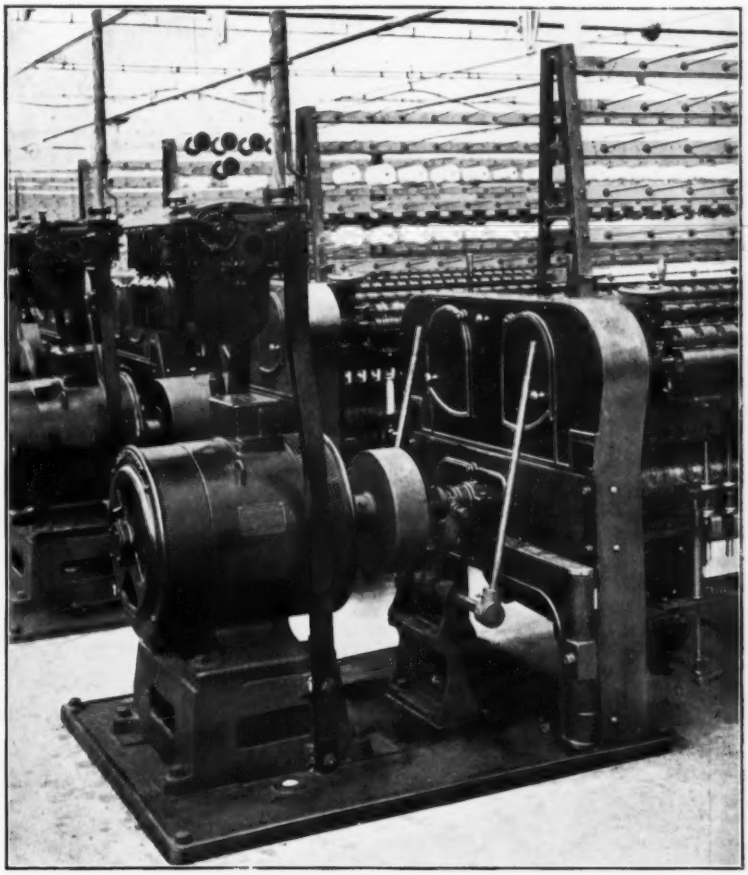


FIG. 5. INDIVIDUAL DRIVE OF DOUBLING FRAMES BY 10 H.P. MOTORS.

For the card rooms three standard sizes of motor were adopted, 50 H.P. for driving cards, 70 H.P. for driving roving frame shafts and 150 H.P. for driving ring frame shafts; in each card room there are six 50 H.P., four 70 H.P. and four 150 H.P. motors.

In the case of the roving frame and ring frame shafts, the motors are direct-coupled through flexible couplings and run at 485 r.p.m. but the card shafts are driven by laminated leather belts, the motors being of the three-bearing-bedplate type running at 585 r.p.m.

Particular attention was given to the design of the motor supports to ensure satisfactory alignment between motor shafts and line shafting and also to enable any motor to be replaced as quickly as possible if necessary.

The motors were manufactured at the Bradford Works of The English Electric Company to their standard designs and are fitted with ball and roller bearings; the flexible couplings, which are of the "pin" type, were also made by the same firm. The performance of these machines up to the present has more than justified the adoption of the type of motor and drive decided upon.

The control gear for each motor is mounted

on the motor staging alongside its motor and consists of a triple-pole oil switch, interlocked with an oil-immersed metallic type rotor starter, the oil switch in every case being fitted with no-volt and three overload releases and ammeter. Push buttons for readily stopping any motor in case of emergency are provided at suitable points in the rooms.

The equipment in the doubling room is similar to that described above, but the motors are each 250 H.P. and are fitted with ring oiling sleeve bearings.

completed and in the case of the 250 B.H.P. motor, Fig. 2, ventilating ducts had not been fitted, and the hand-railing, etc., on some of the motor stagings was not quite completed. Fig. 3 and Fig. 4 however, clearly show the arrangement of the ventilating ducts, the 50 H.P. motors being arranged to discharge their cooling air into the room and the larger motors being provided with an outlet duct in which suitable provision is made for discharging into the room when required, so that the warm air from the motors

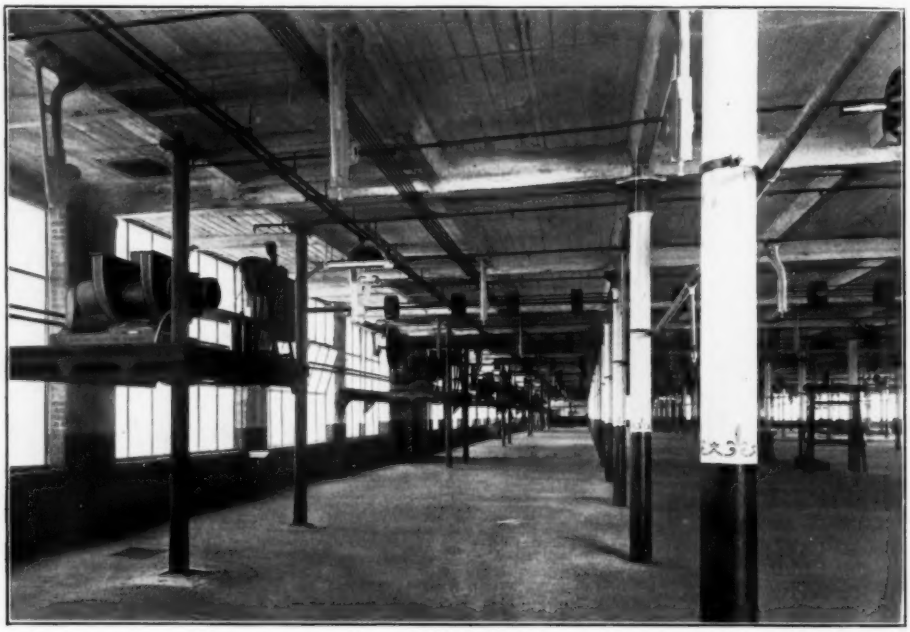


Fig. 6. No. 5 Flat with Line of 50 H.P. Motors.

Amongst the illustrations which show typical views of the installation, special mention may be made of Figure 5, showing the individual drive system applied to a doubling frame, one of a number so equipped in one of the Weaving Sections. These motors are of the squirrel-cage type, specially designed for large pull-out torque, and drive the frames through clutch couplings. Fig. 6 gives a good idea of the size of the individual rooms and shows No. 5 Flat with a line of 50 H.P. motors for belt drive.

The photographs of motors in the Spinning Mill were taken very shortly after erection was

may be utilised in the cold weather to assist in the heating of the Mill.

In conclusion it may be said that the design of this Mill would have been impracticable but for the possibilities of electric driving. The Mill shows very decided advances upon the usual design of Mill for ring spinning, and by incorporating electrical driving in the original design it has been possible to take full advantage of the facilities obtained by the use of electricity in a manner which can rarely be achieved when converting to electrical drive a Mill originally built for mechanical drive.

Factors which Influence the Size of Rolling Mill Drives.

By L. ROTHERA, B.Sc., A.M.Inst.C.E., M.I. & S. Inst.

When the installation of a new rolling mill is being discussed, the three main considerations which come into question are :—

(1). The capital cost of the equipment.
(2). The class of finished product to be rolled.
(3). The disposal of the output.

These three considerations do not at first sight seem intimately bound up with the size of the motor necessary for the mill, but a study of the relationship between them will show that they all have a determining influence if the most economical results are to be obtained relative to the initial cost.

Taking the three considerations in order, the capital cost, starting from the motor end of the plant, is determined by the mutually dependent items of the driving motor, the size of mill, the number and capacity of heating furnaces, area of buildings, etc.

The class of finished product, *i.e.*, the sections to be rolled, determines the size of the motor from the maximum torque requirement, whilst the disposal of the output, on which is dependent the output per hour, fixes the size of the driving motor from the heating point of view.

It thus becomes very necessary to consider how the size of the motor is affected by variations in the above conditions, and the following curves and examples show the relative effect of :—

The choice of section to be rolled,
The output required, and
The methods of rolling.

With this knowledge available it is possible to determine with considerable accuracy the conditions for which the new mill should be designed, in order that the maximum return may be made on the capital expenditure involved.

Choice of Sections to be rolled.—In Fig. 1 are shown three curves, in which are plotted work done (in horse-power hours) against elongation for rolling out three different sections. The three curves (A, B and C) represent the work done in rolling—

A. Girders.
B. Bullhead rails.
C. Billets.

The curves are drawn starting from the same dimension and weight of ingot and finishing to the same weight per foot run of final section.

It follows from these curves that to roll a girder of the same finished weight per foot as a rail or billet, a considerably larger motor will be required, and this fact is accentuated by the reduced number of passes that it is possible to cut in the rolls in the case of sections. This does not preclude, however, the possibility of rolling a lighter girder section with the same driving power as the heavier billets or rails,

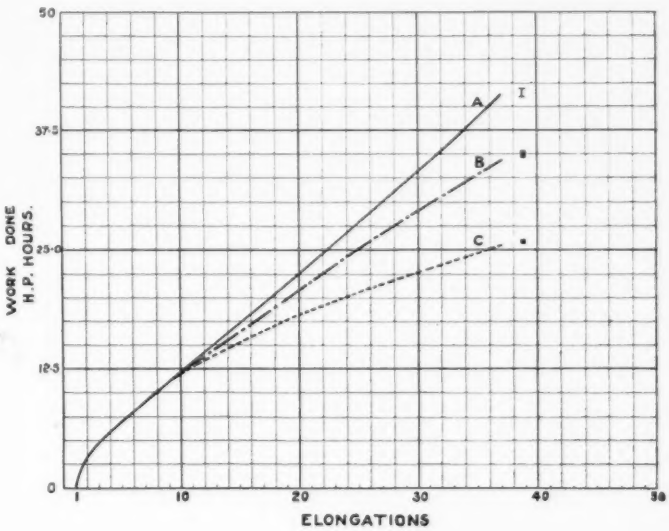


FIG. 1.

and it thus becomes of great importance to fix the limiting size of any section to be rolled before the plant is put down.

It is realized that this is an extremely difficult problem in view of the uncertainty of future demands, but it is necessary to make such decisions before the size of the motor can be properly determined.

The power demand for various sections may be amplified as follows :—

Least power is taken for rolling rounds.

Squares and flats take slightly more.

Angles, tees and bullhead rails a still greater amount, whilst channels and girders produce the heaviest demand.

It must be borne in mind that it is a much better proposition to work a motor on light-load occasionally than to do the reverse and work it on full-load occasionally, and if by the elimination or transference of a larger section to another mill a smaller motor can be installed, a cheaper product will result over the whole range of material rolled, on account of the reduced capital cost of the plant and the better efficiency of the motor.

Output required — Having decided on the sections to be rolled, the next question to be dealt with is the output required. It can be stated generally that the larger the output the less proportionately the capital cost involved. This result is illustrated in figures 2, 3 and 4.

In Fig. 2 are shown side by side the power demand of a single Tinplate Hot Mill and two Hot Mills working simultaneously on "singles."

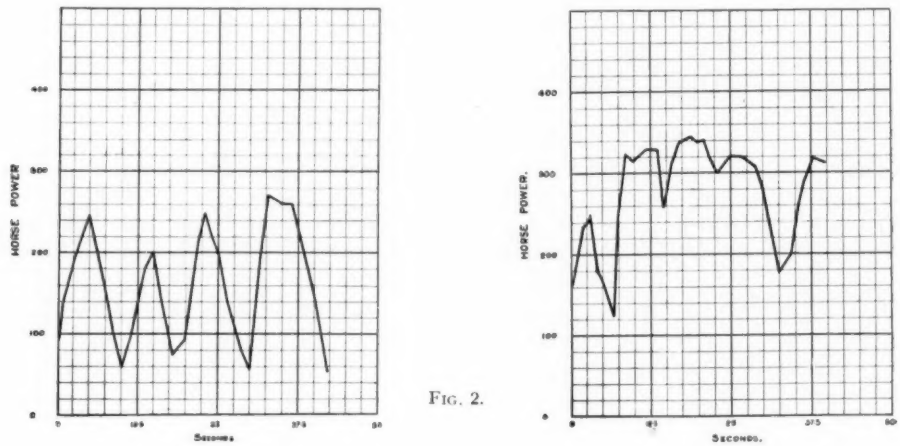
Assuming, for purpose of comparison only, that it is permissible to install a motor of such size that the peak load demand does not exceed 50% overload, the size of motor necessary for one mill would be 180 h.p., and for two mills 220 h.p. There is thus, for double the output, an increased cost on the motor of approximately only 23%. (In actual practice, considerably less than this).

The cost of furnaces will be increased proportionally to the output, whilst the cost of mills, taking into account the flywheel, will be somewhat less than double the cost, so that there is considerable relative overall saving as compared with the increased output.

The same effect occurs in the case of a Merchant Mill, and in Fig. 3 two curves are contrasted taken from a 12″ Merchant Mill showing the power required to roll a $3\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ angle from a $4\frac{1}{2}''$ square × 4′ 8″ billet, in the first case with one piece of metal in the rolls, corresponding to an output of 6-tons per hour, and secondly with two pieces of metal in the rolls at once, giving an output of 12 tons per hour.

Assuming the same 50% overload permissible on the motors, a horse-power of 200 h.p. would be required in the first instance, and 245 h.p. in the second. Here again for double the output only a 20% increase in power would result.

The mill, in this instance, would have the same cost for either condition, but the furnace capacity would have to be increased—probably at something less than double the cost.



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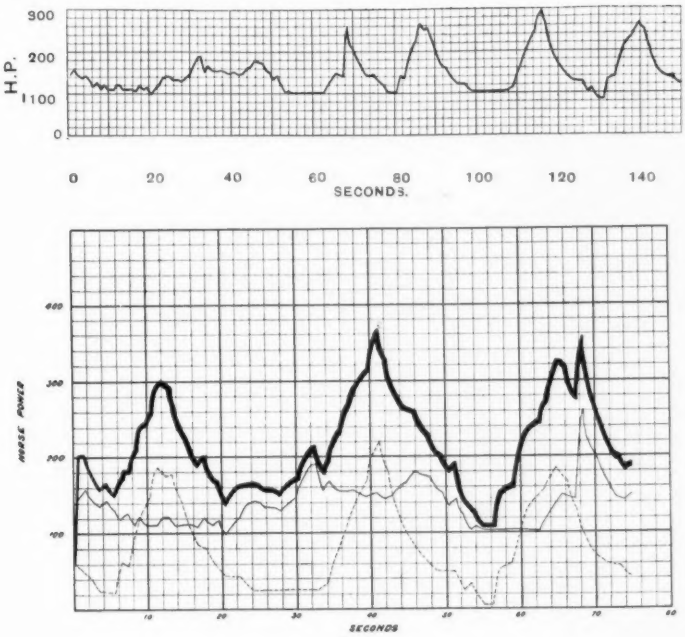


FIG. 3.

may be drawn to the equalizing effect of superimposed fluctuating loads, and with a number of pieces going through the rolls, the percentage variation in power becomes less and less until the final stage is reached of a continuous mill where the loads are practically constant.

In the same way, if a number of mills are working from one power unit, the load demand on the station approaches a steady value.

The deduction drawn from the foregoing is to the effect that the larger the output the less per ton will be the interest and depreciation charges on the plant, whilst overhead charges due to buildings, will be reduced.

It is with this consideration in mind that the present tendency is to push outputs up as much as ever possible, and American practice is an example of what can be done in this way.

Fig. 4 is taken from a Wire Rod Mill, and the curves contrast the power with a single piece passing through the rolls, and with two pieces passing simultaneously.

In this case for double output the motor power increases by only 33%—actually somewhat more to allow for extra heating of the motor.

No alteration would result in the cost of the mill, but some increase would occur in the cost of the furnace.

For purposes of the above comparisons, it is sufficient to work on the peak loads of the mills, but in certain cases such as shown in Fig. 4, the heating value of the motor would also have to be taken into consideration.

In passing, attention

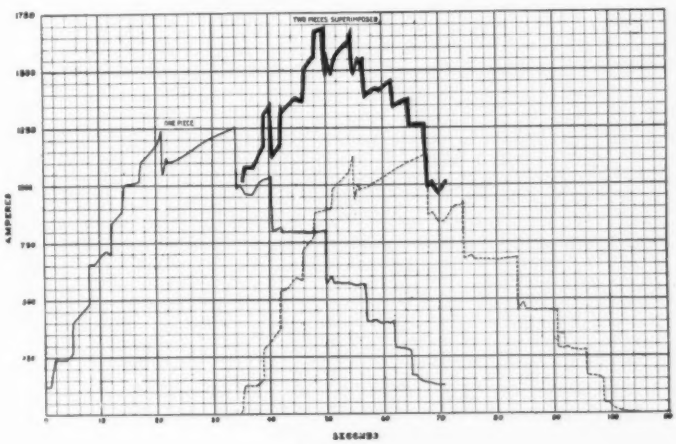


FIG. 4.

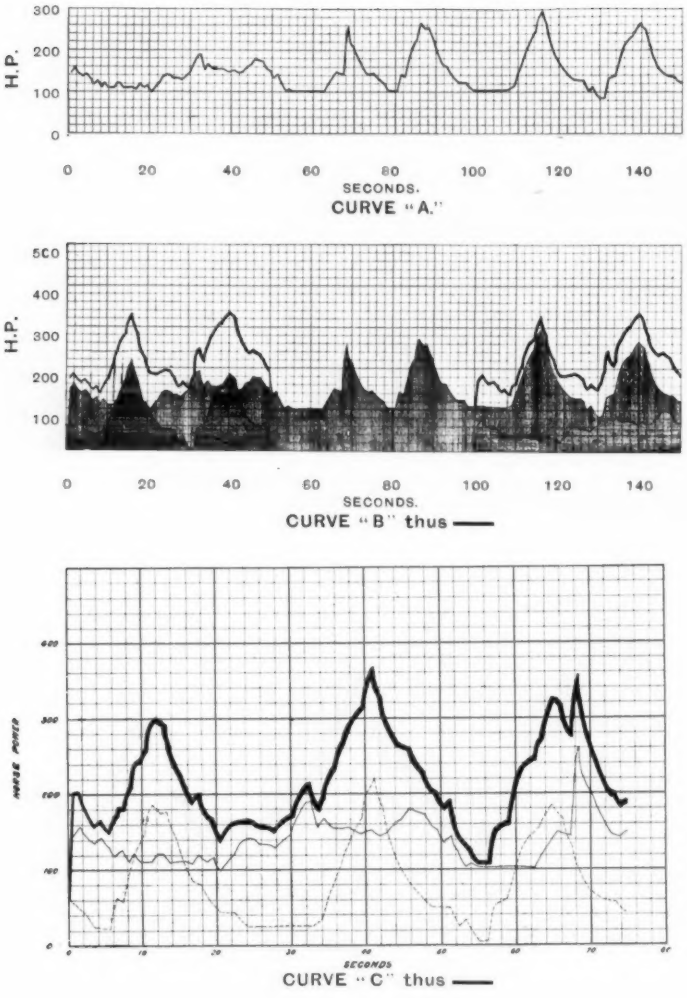


FIG. 5.

The question of very large outputs from mills in this country has only within quite recent times been seriously considered, and previous practice has been to make use of mills on general merchant work which, entailing as it does comparatively small orders and frequent roll changes, prevents any possibility of heavy tonnages. There are, however, a number of recent examples where mills have been put down specially designed to deal with large outputs, and this, in some cases, has been rendered possible by an amalgamation of certain interests whereby a particular class of orders is dealt with in one Works. By far the greater proportion of mills in this country are still on general merchant work, and in such cases special attention must be given to the problem of output, and it is essential that the capital cost of the plant should be reduced to a minimum in order to enable them to compete with mills working on large outputs.

Given this condition a small mill in periods of bad trade will have an advantage over a large plant, in that it will find a market for its product and can continue working when it is uneconomical to keep the large plant in operation.

Methods of Rolling.—In a number of instances it would appear possible to limit the size of motor by adopting methods of rolling which are not general at the present time, and in Fig. 5 the same curve is taken as is shown in Fig. 3, and the effect of superimposing two pieces at different intervals is contrasted.

Curve "A" shows one piece of metal going through the rolls only, with a resultant output of 6 tons per hour.

Curve "B" has two pieces superimposed, with a resultant output of 9 tons per hour.

Curve "C" shows two pieces again superimposed, with an output of 12 tons per hour.

The relative horse-power demand in the three cases, assuming, as before, 50% permissible

overload on the motor to deal with peaks, would be :—

Curve " A " .. 200 h.p.
" " B " .. 225 "
" " C " .. 245 "

The average output required from this mill was between 4 and 5 tons per hour, but the normal method of rolling was to have two pieces in the mill at the same time, so that a peak load either of 338 h.p. or 370 h.p. may result, requiring motors of alternatively 225 h.p. or 245 h.p., whereas if the mill had been definitely limited to one piece of metal at once, a motor of 200 h.p. could have been installed. Incidentally, this curve shows with what a small increase in driving power the output can be raised from 9 tons to 12 tons.

Fig. 6 shows again the curves of Fig. 2.

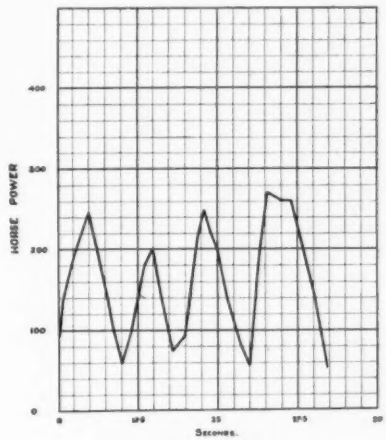
Curve " A " showing a single mill working.
" " B " showing two mills with the loads breaking joint.
" " C " showing actual rolling conditions.

Here again, if the method of rolling as shown in Curve " B " had been adopted, the same output would have been obtained as is actually obtained in Curve " C," with a motor of 200 h.p. instead of 220 h.p. From the heating point of view the relative figures would probably be 225 h.p. and 260 h.p. respectively.

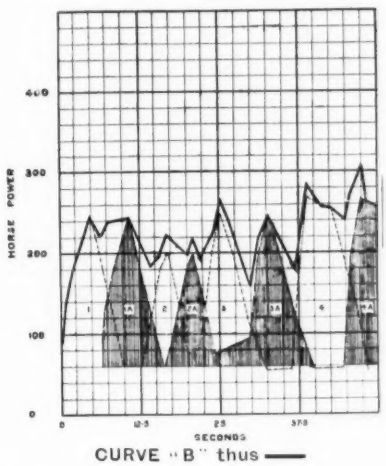
It will be objected that if men have to watch one another so that the passes on the two mills break joint, the output will be affected. This result is almost entirely apparent and not real. The output over a short period may be reduced, but the hourly output will suffer little or no reduction.

It will be interesting to have the views of those responsible for mill output on this question, as it appears to open a field of investigation which might lead to beneficial results all round.

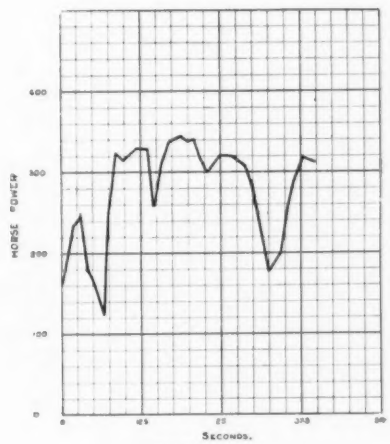
In the foregoing it has been assumed that a definite programme has been adopted to which



CURVE "A."



CURVE "B" thus ——



CURVE "C."

FIG. 6.

the mill will work without taking into consideration future requirements and extensions. These can be met in several ways—

Firstly, by replacing the original motor by a larger one.

Secondly, by installing a motor, in the first instance, with a considerable reserve of power.

Thirdly, by putting down a new mill.

It is common experience to find that if a motor of excessive power is put down in the first instance, means are very soon adopted whereby full advantage is taken of the excess, but this does not overcome the difficulty that on a considerable number of the smaller sections the motor will be working on light-load, with resulting reduction in the overall efficiency, and an example is given to illustrate how this works out in practice.

Take, for example, a 12″ mill driven by a motor of sufficient capacity to meet the original requirements, say 250 h.p., and the same mill equipped with a 400 h.p. motor to meet future requirements. The approximate relative costs of the two equipments, would be :—

For the 250 h.p. Set .. £2,600 0s. 0d.
For the 400 h.p. Set .. £3,900 0s. 0d.

The extra capital cost involved for the second machine is, therefore, £1,300 0s. 0d.

Taking interest and depreciation on this value at 17%, the loss per annum would be £220 0s. 0d.

The second machine working on light-load would have an overall efficiency of approximately 2% less than the smaller machine.

Taking an output from the mill of 25,000 tons per year, and an average power demand of 40 units per ton, the total units consumed would be 1,000,000, which at the rate of one penny per unit would represent an annual charge of £4,160 0s. 0d.

The loss per annum due to the 2% reduction in efficiency would be £83 0s. 0d., which, added to the interest and depreciation loss, would make a total of £303 0s. 0d.

These figures enable us to form an opinion as to which course to adopt, and it would appear that if the programme remains unaltered for five years or more it will be best to install the small machine, whereas if an alteration to the programme results in less than five years, the larger machine should be installed, unless the third possibility is adopted, namely, of putting down a new mill for dealing with the larger requirements. This result follows from the following figures :—

In five years' time the relative loss entailed by installing the larger motor would be £1,515.

Assuming that the value of the 250 h.p. motor at the end of the same period was more than £1,000 0s. 0d., which is a fair assumption to make, the summation of the loss and the value of the motor would be in excess of its cost, thus making a case in favour of running the small motor for this length of time and then changing it.

Draughting of Rolls.—A most important influence in the size of motor required is the draughting adopted, and in the past the roll turner has concentrated on obtaining the final required section without troubling, to any extent, as to the power taken in the individual passes—in fact, it is usual experience when carrying out a test on a steam-driven mill to have a statement made, to the effect that pass so and so is the one which takes most pulling through. Now that the electric drive enables a continuous record to be taken in graphical form of the power demand on any pass, this state of affairs should no longer exist, and the passes should be so graduated that an approximately equal power demand should occur throughout the passes.

It is interesting to know that in one large recently equipped plant the procedure adopted when rolling a new section is to submit the power curve of the first piece rolled to the Electrical Engineers' Office, which criticises the draughting, and alterations are made accordingly if found to be necessary.

This suggestion that draughtings should be altered in order to limit the loading conditions is likely to meet with a good deal of opposition to begin with, until the beneficial effects are realized.

Fig. 7 shows the result of a test taken when rolling a 5″ square billet down to a light section rail weighing about 9 lbs. per yard, the power demand per pass being shown by the rectangular curves, and the corresponding horse-power demand from the motor by the parabolic curves.

The first five passes represent roughing passes during which the power demand from the motor is very small.

When the finishing passes are reached it will be seen that the fifth finishing pass requires a peak on the motor of 570 h.p., whereas no other pass requires more than 380 h.p.

Working again on a 50% permissible overload as limiting the size of the motor, it would be necessary to install, to deal with this one pass,

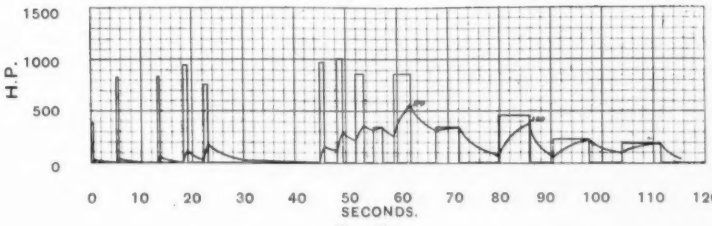


FIG. 7.

a machine with a normal rating of 380 h.p., whilst if this one peak was reduced to a limit of 380 h.p. a motor of 255 h.p. could have been adopted.

The first, fourth and sixth passes in the finishing are quite small, and by a re-arrangement of the draughting there is little doubt that the maximum peak could have been reduced to 380 h.p. or even possibly less.

When the roll turner has at his disposal a curve of motor power, as shown here, it enables him to re-organize his passes with a view to removing any undue power demand.

Number of Passes taken.—Closely bound up with the question of the draughting is, of course, that of the number of passes taken to produce the finished product.

Practice varies very considerably in this respect, and is frequently governed by the length of the barrel of the rolls which enables only a certain number of passes to be cut in the length.

In order to show the effect of varying the number of passes, two curves are contrasted, Fig. 8, in which is shown the rolling out of a flat bottomed rail, 100 lbs. per yard, from an 8″ ×8″ billet in alternatively eleven and nine passes. The reduced number of passes will result in a considerably increased output, as the time saved during rolling will be possibly 20%, but, on the other hand, assuming only a definite output per hour is required, which can be obtained if eleven passes are taken, the horse-power demand is reduced from 4,160 h.p. to 3,160 h.p., and the size of the driving motor can be correspondingly reduced with reduction in cost. It is probable that the extra number of passes will require a somewhat greater length of barrel, without, however, any increase in the diameter of the roll, although this also may be necessitated, and the increase in cost due to this would have to be offset against the saving in the cost of the drive.

Summarizing the foregoing, the conclusions reached can be stated as follows :—

(1). Assuming suitable facilities and the necessary market for finished product, the larger the output the smaller the relative capital cost, and the reduced cost per ton rolled.

(2). By limiting the sections to be rolled in any one mill, the capital cost is reduced and a more efficient plant results.

(3). By arrangement of the method of rolling, a cheaper plant can deal with the same output.

(4). By studying the power demand for any particular draught, modifications may frequently be made in such a way as to reduce the size of motor required, and thus influence favourably the capital cost.

The above conclusions serve to indicate the lines along which an investigation should take place with a view to limiting the cost of the plant, and consequently the cost of the finished product, but the relative importance of the various factors varies from case to case, and can only be decided when all the sides of the problem are known. It is hoped that this article will, at any rate, help those intending to put down new plant to determine the most favourable conditions under which it should operate.

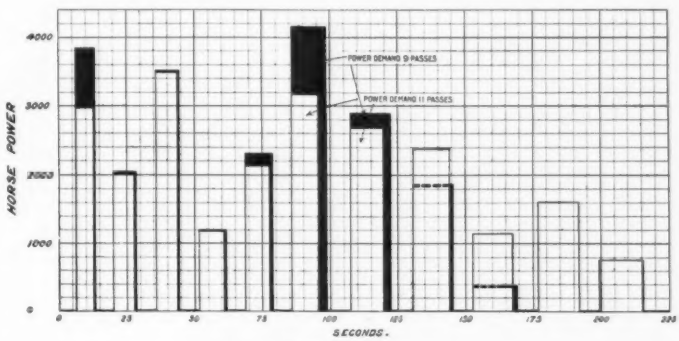


FIG. 8.

The Oscillating Phase Advancer.

By W. E. Milton Ayres, A.M.I.E.E.

The rapid spread of the industrial application of A.C. motors has lead to a serious condition on the distributing systems and in the generating stations of many electrical undertakings and supply companies. There are extensive systems in operation where the average power factor is below 0·60. What this means in increased capital cost of generators, transformers, and mains can be imagined. To this must be added the loss of revenue due to reduced generator efficiency, increased excitation losses, and increased losses in distribution.

There is considerable evidence that electrical supply companies are awakening to the seriousness of the position, and differential tariffs have been introduced or are contemplated which will favour a high average power factor on the consumer's system.

The question is equally of interest to the consumer. At least one enterprising works engineer, when ordering A.C. motors, figured out the cost of his cabling and switchgear, also added the capitalized cost of his distribution losses, to find the overall cost of each motor installation. In a known instance he accepted the highest of three motor tenders, as the overall cost thus ascertained was lower on account of 4% better power factor.

In general, induction motors should be used at as high a speed as practicable and so grouped as to maintain a high load factor. There are, however, numerous instances where a comparatively low speed gives a more economical drive and where, due to heavy peak loads or severe starting conditions, a low load factor is unavoidable. In such cases a phase advancer is of special benefit, but even in existing installations, containing fairly large slip ring motors, the addition of phase advancers to those motors will reduce the cost of power. This is due to the fact that the addition of a phase advancer to the larger units, even if such motors have reasonable inherent power factors, will recover a large amount of wattless K.V.A. and considerably improve the power factor of the system.

Power Factor correction should be applied at the source of the mischief if full use is to be secured of the distribution lines as well as of the substation apparatus, the main transmission line, and the power house plant. The real point of application, where practicable, is, therefore, at the induction motors. Phase Advancers are particularly suitable and economical. They are comparatively small output machines, as they are placed in the rotor circuit, and their effectiveness is magnified inversely as the slip. Other types of apparatus installed solely for power factor correction operate on line frequency and voltage and are therefore of the full K.V.A. capacity of the wattless load recovered. They are, therefore, much more bulky and expensive, and occupy considerably more floor space.

As will be seen later, the output of motors with which phase advancers are used can frequently be increased ; and conversely, for the same output, the size of the motor may be reduced. In large slow speed motors this saving alone will pay for the additional cost of the phase advancer.

The savings which can be effected by the use of phase advancers with induction motors are, therefore, many, and may be summarized as follows :—

(1). Size and cost of motor.
(2). Size and cost of power factor correcting apparatus, as compared with devices used at line voltage and frequency.
(3). Reduced cost of distributing system.
(4). Reduced cost of substation transformers and apparatus.
(5). Saving in distribution losses.
(6). Saving in generating plant.
(7). Reduced capacity of synchronous-condenser plant at the distributing substations on large power schemes.

In addition to these important items is the differential tariff favouring high power factor, which in many cases will reduce the power bill to a degree out of all proportion to the cost of the phase advancer.

Phase advancers, however, are not suitable for intermittently running motors, such as crane equipments, for motors requiring variable speed, or for motors used with a slip regulator.

The oscillating phase advancer is a very simple, self-acting apparatus, which can be

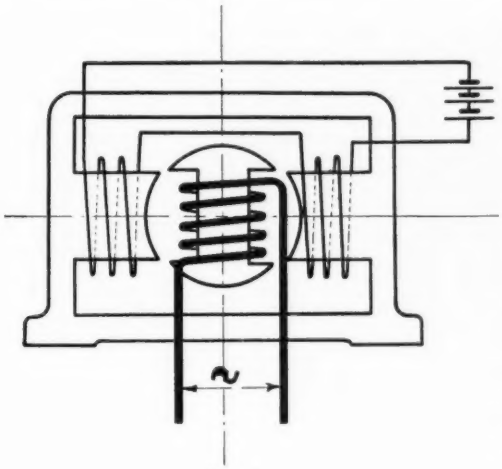


FIG. 1.

connected to the rotor circuit of any slip ring induction motor and requires no mechanical drive whatever.

The elemental phase advancer is shown in Fig. 1. It will be quite evident from the illustration that if a low frequency current is applied to the armature, in a separately excited constant field, the armature will oscillate so as to bring its magnetic axis into line with the polar axis of the field, first in one direction and then in the other alternately as the armature current changes direction.

If, instead of the armature shown, we substitute a distributed winding and commutator similar to an ordinary D.C. motor armature, and again apply the low frequency current, the armature will accelerate in one direction, decelerate and repeat the action in the opposite direction, passing through zero speed twice each cycle. The maximum speed attained in either direction will be limited only by the moment of inertia of the armature, the length of time (one quarter of a cycle) in which to accelerate, and the tangential force on the armature due to interaction of the field and armature current.

In Fig. 2, (*a*) represents an alternating voltage due to the rotor slip of an Induction Motor, with the rotor current slightly lagging, on a time base.

The armature torque, and hence the acceleration, is proportional to the rotor current, so the armature acceleration may be represented as at (*b*) by a curve identical in magnitude and phase with the current.

Maximum acceleration will take place when the armature passes through zero speed, and zero acceleration when the armature is at its maximum speed and just about to decelerate. The speed will, therefore, be represented by a curve lagging 90° behind the acceleration curve as shown at (*c*).

When the armature is accelerating in speed it will draw electrical energy from the slip rings and convert it into kinetic energy. The advancer will then be motoring. When, however, the armature is decelerating it will give out this stored energy by converting it into electrical energy and then acts as a generator. Thus the advancer is twice a motor and twice a generator during each slip cycle.

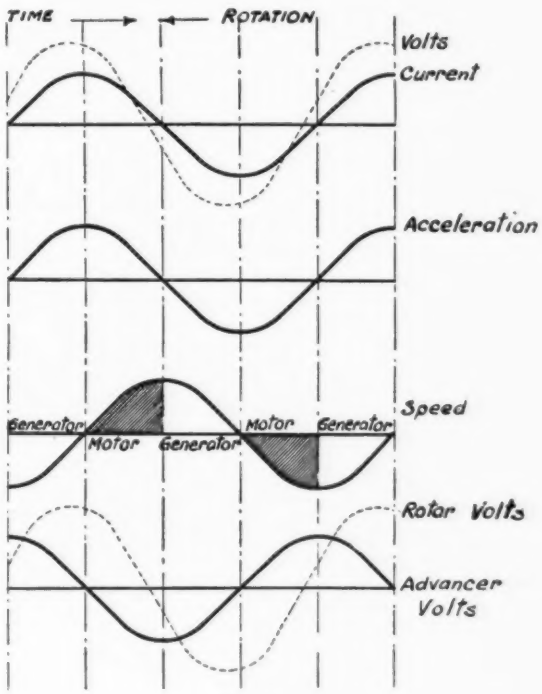


FIG. 2

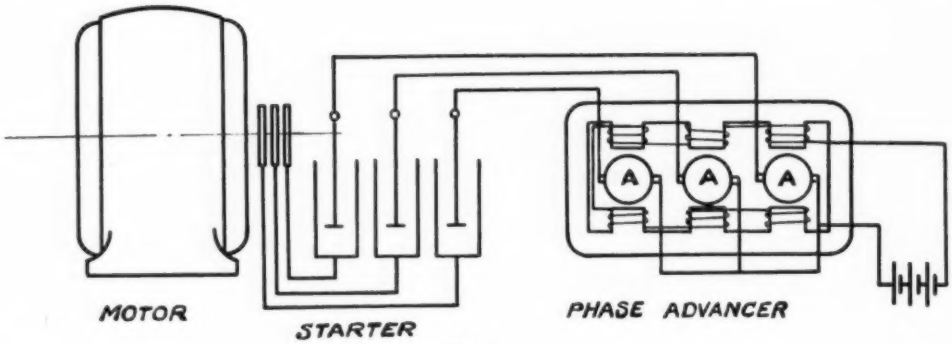


FIG. 3

When full line periodicity is impressed upon the advancer with the motor stationary, as at the moment of starting, the advancer armature will merely quiver. As the motor speeds up, and the rotor frequency comes down, this motion will grow into the full oscillation intended.

Maximum phase advancer voltage will be produced at maximum armature speed. When the phase advancer is motoring, this voltage will be a counter EMF, and of opposite sign to the rotor voltage. Conversely, when the phase advancer is generating, the voltage will be of the same sign as the rotor voltage. By plotting this suitably for each quarter cycle the advancer voltage is as shown at (*d*) in Fig. 2, and it will be seen that this is a leading voltage. The current due to this voltage will be a leading current on the induction motor and will, therefore, act as a magnetizing current, so that less lagging current will be drawn from the line and the power factor of the motor will be improved.

Oscillating phase advancers are essentially single phase machines, so a separate armature is used for each rotor phase. These three armatures, for the usual three phase rotor, are accommodated in one housing either side-by-side as shown in Fig. 3, or in the larger sizes as a triangular arrangement as shown in Fig. 4. The armatures may be connected in Star or Delta as required, according to the rotor current to be dealt with. The Delta

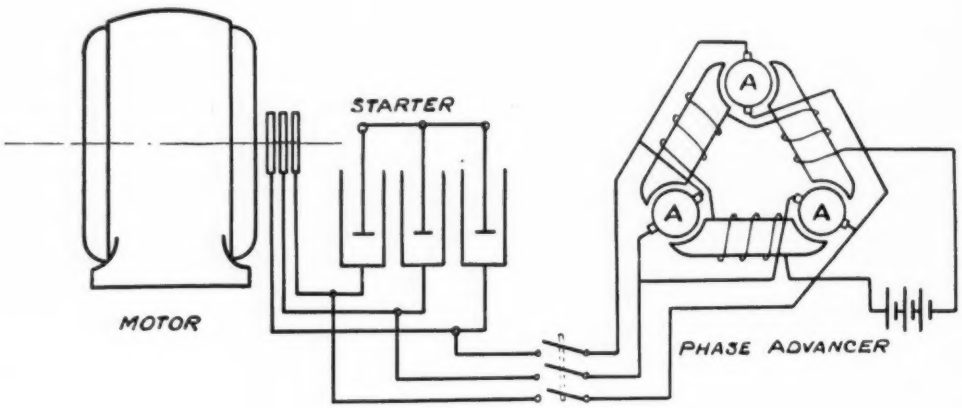


FIG. 4.

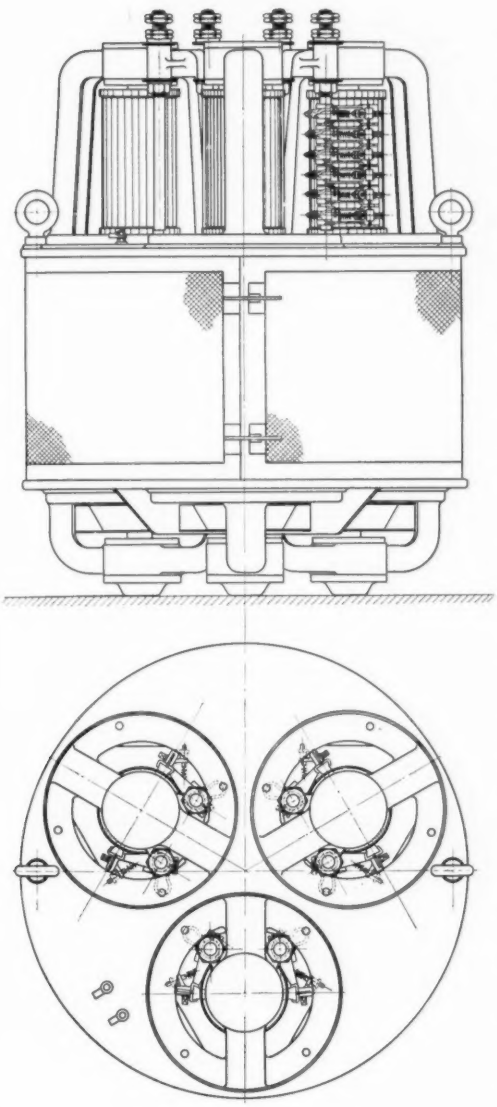


FIG. 5.

connection gives only 57% of the rotor current per commutator.

Figs. 3 and 4 show also the diagram of connections to the motor secondary. If a starter of the type which does not necessarily make the neutral point is provided, then the phase advancer may make the neutral and no extra switchgear is required. If the type of starter used makes the neutral of the rotor circuit, a 3 pole switch must be provided as shown in Fig. 4. This switch is open whilst starting the motor, then closed, and finally the resistance circuit is opened.

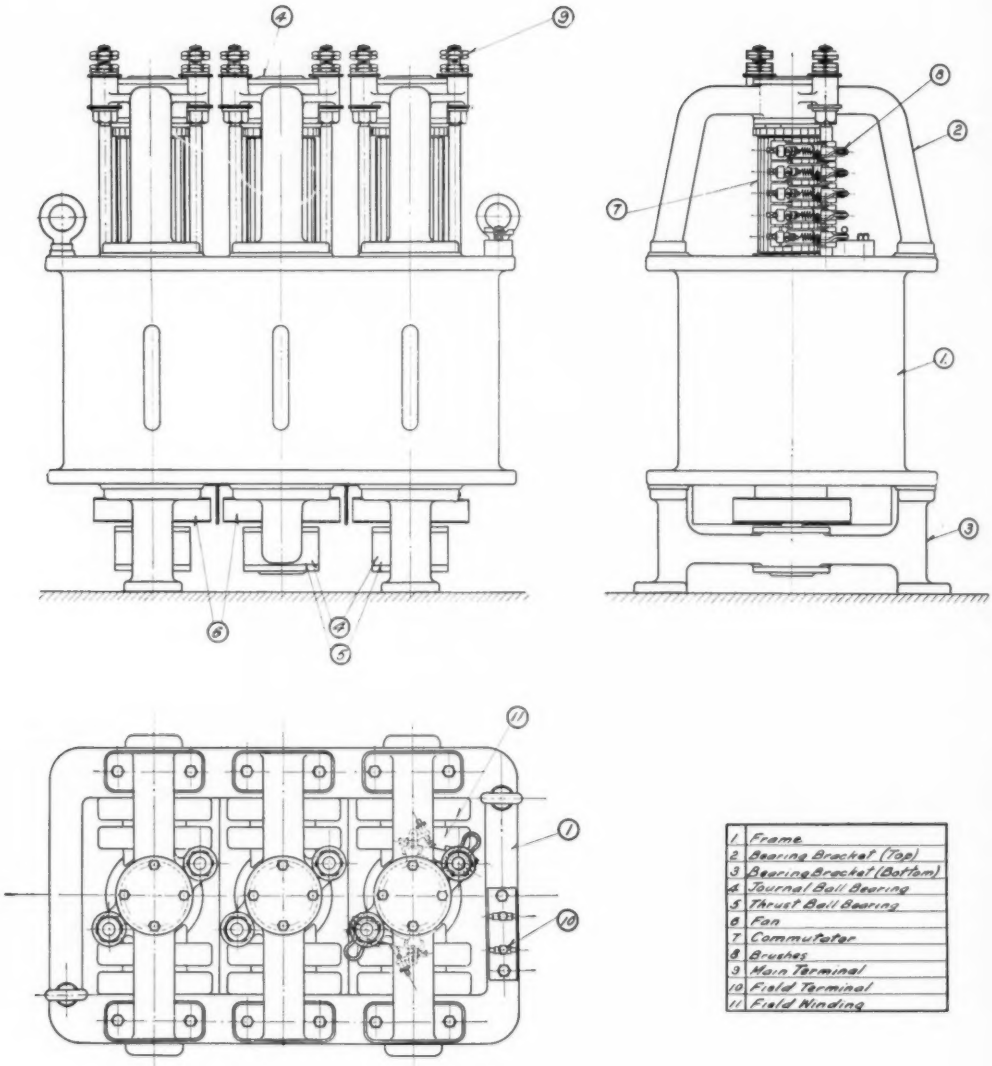
Figs. 5 and 6 show drawings of the two standard types of oscillating phase advancers. It will be noticed that the armatures are very long and of small diameter. As previously seen, the maximum speed attained by the advancer, and therefore the voltage generated by rotation, is inversely proportional to the moment of inertia. The moment of inertia varies with the mass times the square of the diameter of gyration, and since the mass varies with the volume, the moment of inertia varies as $D^2L \times D^2$ or D^4L. Hence the diameter affects the output inversely as its fourth power, and consequently is kept very small.

The armatures are mounted vertically and on ball bearings, whilst the brush gear is specially designed for the continual reversals of rotation.

Fig. 7 shows part of the circle diagram of an induction motor with and without the phase advancer. The full line semi-circle is the locus of current for the motor without advancer. The inclusion of the phase advancer makes this current locus follow the distorted circle and the wattless K.V.A. recovered is shown by the abscissae as " a-b," separating these two current loci.

By using a phase advancer the pull out torque of a motor is increased, owing to the reduced resultant reactance. Advantage can be taken of this in slow speed motors which are specially designed for use with phase advancers.

The performance curves of a motor with and without phase advancer are shown in Fig. 8. The motor is a standard type L.S. 2409 Induction Motor, 1250-h.p., 3-phase, 50-periods, 1000-volts, 16-poles, and the Oscillating Phase Advancer, Type V.13, connected Delta. The following particulars relating to this equipment are of interest :—



1	Frame
2	Bearing Bracket (Top)
3	Bearing Bracket (Bottom)
4	Journal Ball Bearing
5	Thrust Ball Bearing
6	Fan
7	Commutator
8	Brushes
9	Main Terminal
10	Field Terminal
11	Field Winding

FIG. 6.

Full load power factor improved from ·86 to ·995.

Full load efficiency increased 0·35% equals a saving of 3·5-k.w. losses.

Full load slip increased 1·25% to 1·75%.

Stator current reduced 14%.

Rotor current increased 5%.

Possible increase of output for equal losses 5·6%.

Advancer armatures $4\frac{3}{4}''$ dia. $\times 8\frac{1}{2}''$ long cores.

Crest speed attained 21·5-r.p.s.

Armatures make 7·8 revolutions between points of zero speed.

Floor space occupied $20'' \times 29''$, overall height $33\frac{1}{2}''$.

A range of six sizes has been standardised and each may be connected in Star or Delta, making twelve variations. The maximum rotor currents for which these are suitable and the excitation required are given in Table 1.

TABLE I.

Ph. Advancer No.	V.10	V.11	V.12	V.13	V.14	V.15
Rotor amps Star	230	280	350	420	500	600
Rotor amps Delta	390	480	600	720	860	1000
Excitation watts	500	500	660	660	800	800
K.V.A. Output 50 ~ 2% slip	150	150	300	300	450	450

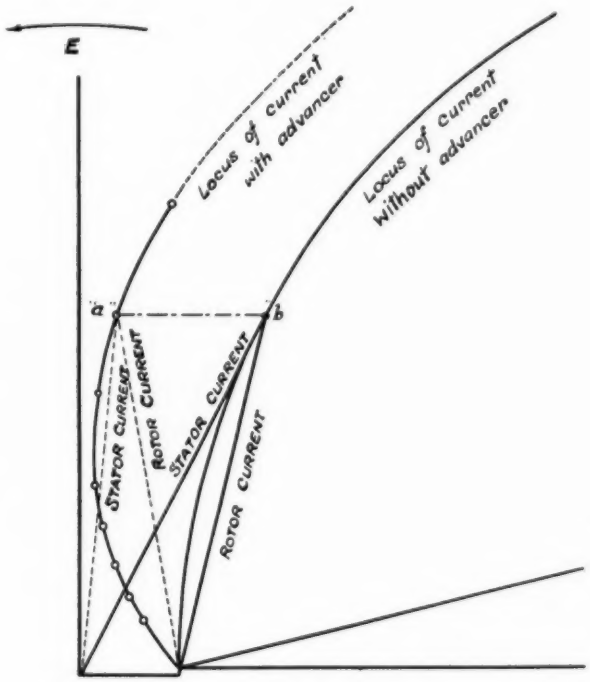


FIG. 7.

The output in wattless K.V.A. recovered is proportional to the current squared, inversely proportional to the periodicity, and inversely proportional to the square of the slip when working with the advancer. The slip when working with the advancer is from 1·3 to 1·8 times the slip of the motor alone, depending upon the degree of correction and ratio of equivalent advancer resistance to rotor resistance. An inclusive slip value of 1·4 times may be taken as a fair average for full load conditions. As the output varies inversely as the square of the slip, it is desirable to keep the slip of motors for use with phase advancers as small as possible. Oscillating phase advancers are scarcely suitable for motors having a slip frequency of more than 2 cycles per second.

The K.V.A. output given in the above table is the wattless load recovered by the Phase Advancer when working at its rated current on a 50 period motor with 2% slip normal, calculated as 2·8% inclusive, with phase advancer. By the above rules this can easily be transformed to find the *approximate* wattless K.V.A. recovered, and corrected power factor, of any other motor which it is desired to investigate.

Example: Find the wattless K.V.A. recovered and the corrected power factor of a 600-h.p., 3-phase, 40-periods, motor with full load rotor amps 560 and normal slip 2·35%. Full load power factor ·80.

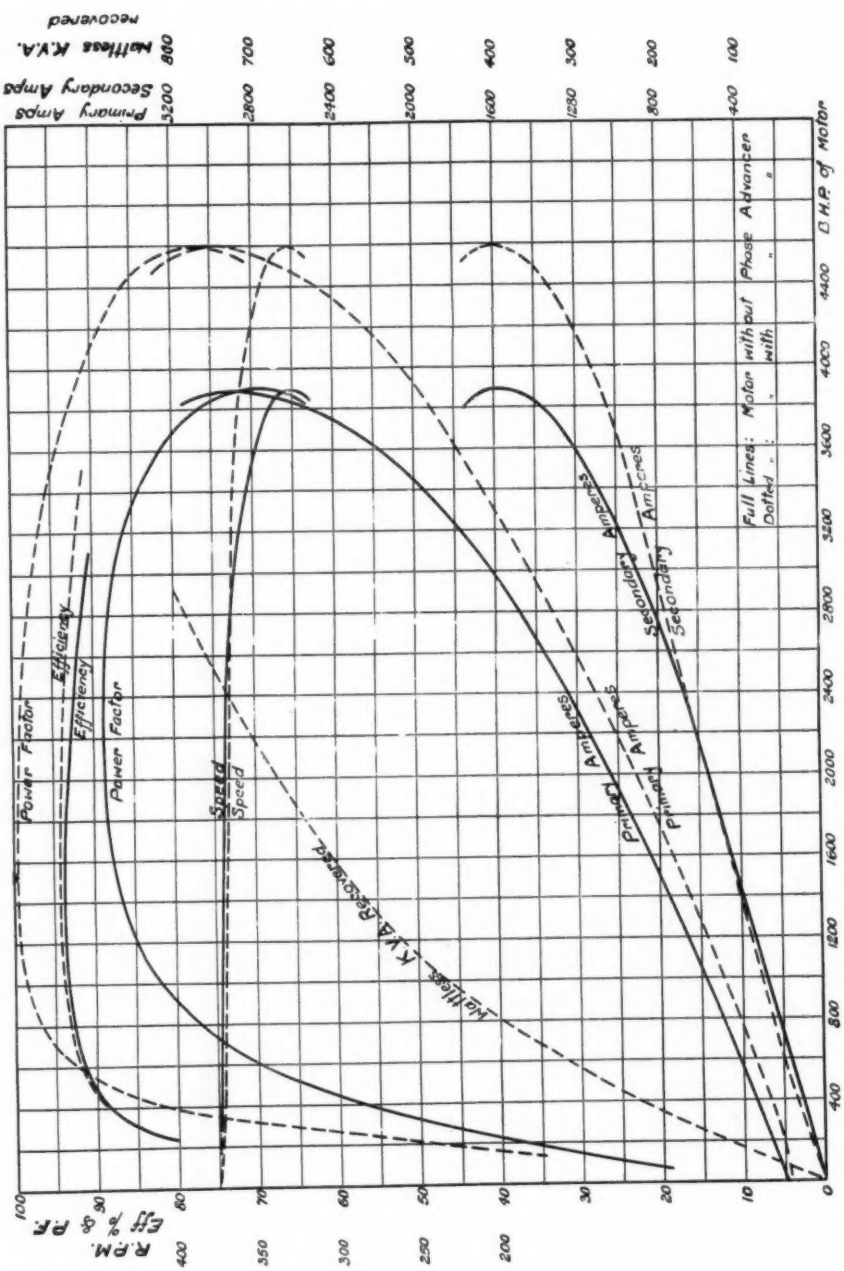

Full Lines: Motor without Phase Advancer
Dotted " : " with " "
H.P. of Motor
Primary Amps
Secondary Amps
Kilowatts K.V.A.
recovered
Power Factor
Efficiency
Efficiency
Power Factor
Speed
Speed
Kilowatts K.V.A. Required
Primary Amperes
Primary Amperes
Secondary Amperes
Secondary Amperes
R.P.M.
Eff % & P.F.

Fig. 8.

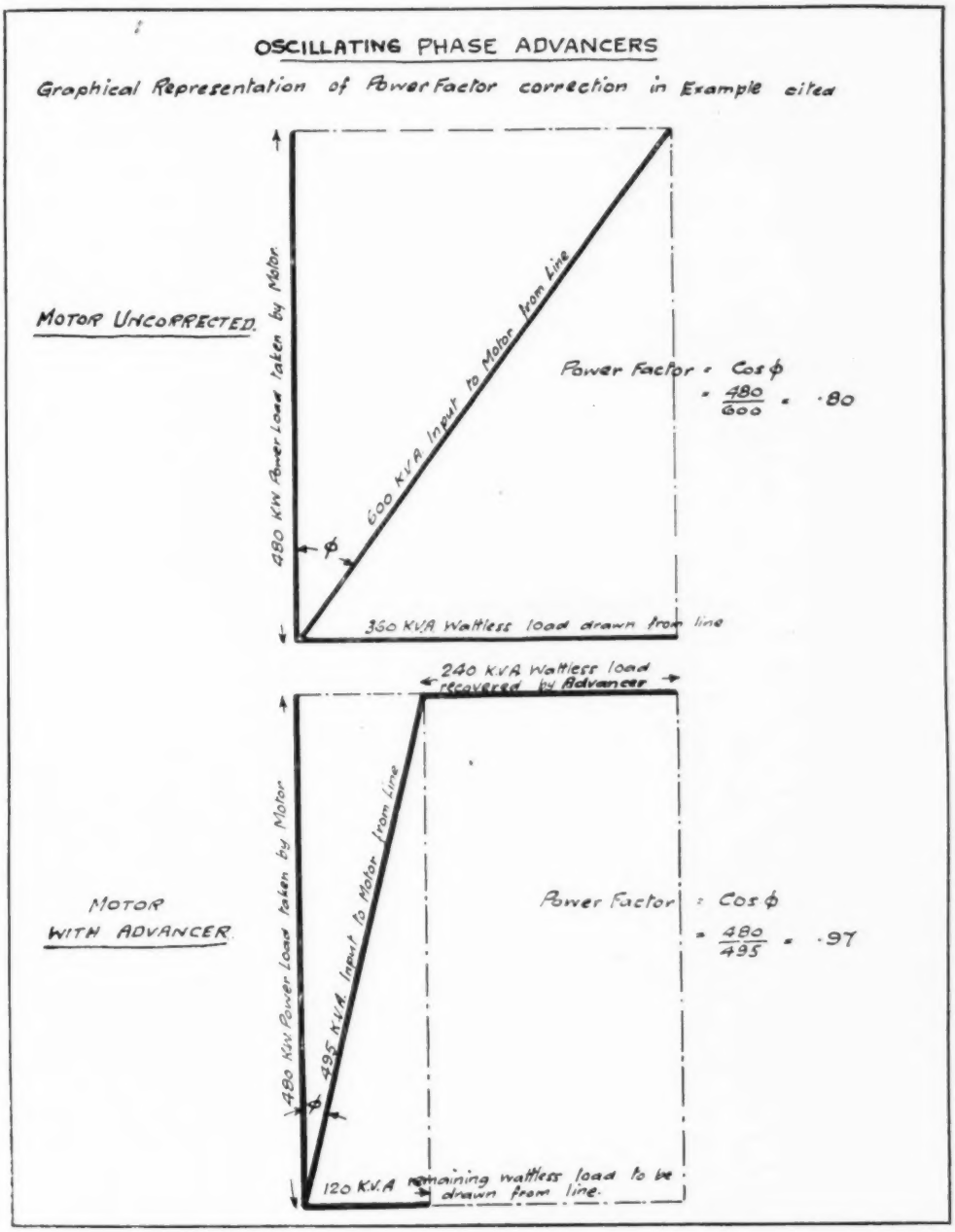

OSCILLATING PHASE ADVANCERS
Graphical Representation of Power Factor correction in Example cited
MOTOR UNCORRECTED.
480 KW Power Load taken by Motor
600 K.V.A Input to Motor from Line
φ
Power Factor = Cos φ
= 480/600 = ·80
360 K.V.A Wattless load drawn from line
240 K.V.A Wattless load recovered by Advancer
MOTOR WITH ADVANCER.
480 KW Power Load taken by Motor
495 K.V.A Input to Motor from Line
φ
Power Factor = Cos φ
= 480/495 = ·97
120 K.V.A remaining wattless load to be drawn from line.

FIG. 9.

Advancer V.12 connected in Delta would be used in this case and has an output of 300-K.V.A. at 600 amps as per table—

$\therefore$ Output on 600-h.p. Motor $40\sim$ =

$$300 \times \left(\frac{560}{600}\right)^2 \times \left(\frac{2}{2{\cdot}35}\right)^2 \times \frac{50}{40} = 240 \text{ K.V.A.}$$

600 B.H.P. at ·80 power factor = 600 K.V.A. input.

K.W. load = 600 × ·80 = 480 k.w.

Wattless component $= \sqrt{600^2 - 480^2} = 360$ K.V.A.

From this wattless component deduct the 240 K.V.A. recovered by the advancer, 360—240 = 120 K.V.A. remaining wattless load.

New K.V.A. input $= \sqrt{480^2 + 120^2} = 495$ K.V.A.

Corrected power factor $= \frac{480}{495} = {\cdot}97$

These power factor calculations are shown graphically in Fig. 9.

If the recovered K.V.A. is greater than the wattless component taken by the motor, the resulting power factor will be leading.

Power factor correction to between ·95 and 1·0 is usually the most economical. Correction to more than unity increases the rotor current rapidly, which means increased losses and, as the slip varies with the current squared, tends to reduce the advancer output, so that a very much larger advancer would be required for a comparatively small increase in recovered wattless K.V.A. On account of the characteristics of the cosine curve this would be accompanied by a negligible improvement in power factor and alteration in stator current to the motor.

SCHEDULE OF INFORMATION REQUIRED with enquiries for Oscillating Phase Advancers.

B.H.P. of Motor.....
Periodicity of Supply.....Voltage.....
Full Load Power Factor.....Slip % (F.L.)..
No Load Current.....
Short circuit current (if obtainable).....
Rotor resistance between rings (hot).....
,, standstill volts between rings.....
,, current per ring (F.L.).....
Is D.C. supply available for Excitation ?.....
State D.C. Voltage.....

Canadian Business.

The English Electric Company have recently completed arrangements which are likely to lead to a considerable extension of their Canadian business.

The English Electric Company of Canada, Limited, has been registered in the Dominion, with a capital of $2,150,000, locally subscribed. The new Company has acquired the works and business of the Canadian Crocker-Wheeler Company, of St. Catherine's, Ontario, and thus comes into possession of a modern works, equipped for the manufacture of electrical machinery, and an established business well known throughout the Dominion. The new Company will extend the range of its products by developing manufacture to English Electric designs and will also act as the representatives of The English Electric Company in Canada, Newfoundland and the United States of America. The use of electricity may be said to be universal in Canada, and as the vast water power resources of the Dominion are developed there is a rapid growth in the demand for electrical machinery and apparatus of all kinds. The formation of The English Electric Company of Canada is the first step which has been taken to meet this demand through the cooperation of British and Canadian manufacturers.

An Investigation into the Properties of a Tramcar Circuit Breaker.

FIG. 1.—EXTERNAL VIEW OF TRAMCAR CIRCUIT BREAKER.

The general tendency towards increase in power in the units operating tramcars has led to the introduction of a circuit breaker which is not only capable of carrying currents and extinguishing arcs of a much larger order than heretofore, but provides ample margin for even a greater increase in power should it be found necessary in the future.

The Dick, Kerr Works of the English Electric Company have for the last twenty years been manufacturing tramcar circuit breakers which have stood the test of successful operation in traction service during the whole of this period. All the experience gained in this work has been used in the design and construction of the circuit breaker described in this article. It is known as the Type D, Form A, Tramcar Circuit Breaker.

The general features of the previous types have been maintained, and the improvements made are in the direction of larger current-carrying capacity, larger contacts and a larger cross section in the magnetic circuit to provide a stronger field for the blowout chamber. Thus the Type D, Form A, Circuit Breaker is a piece of apparatus capable of dealing effectively with dangerous rises of current or any short circuits likely to be met with in traction service, with a margin for still more severe conditions should they arise in the future, and with a very little increase in weight over the previous types.

The outlines of the circuit breaker can be seen

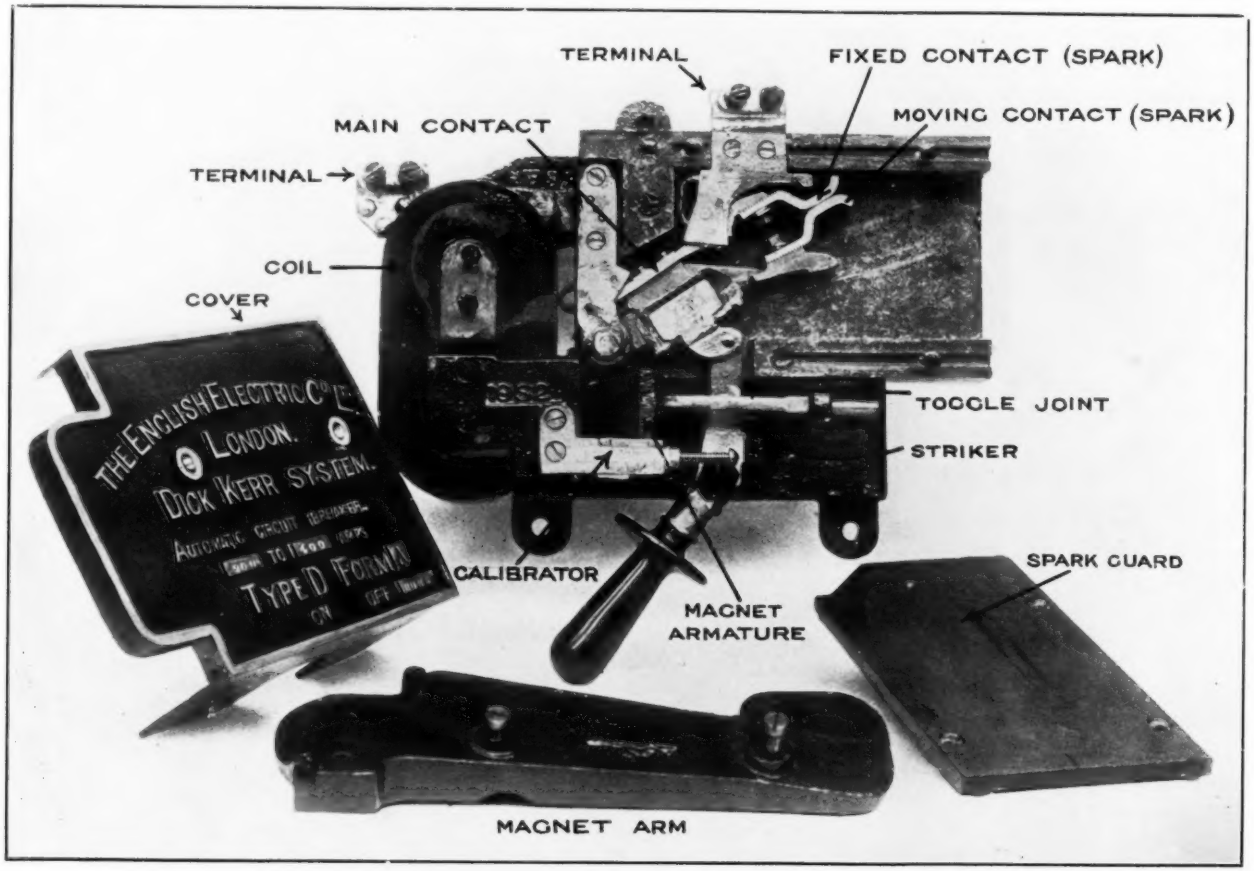

TERMINAL
FIXED CONTACT (SPARK)
MAIN CONTACT
MOVING CONTACT (SPARK)
TERMINAL
COIL
COVER
TOGGLE JOINT
STRIKER
THE ENGLISH ELECTRIC Co LTD
LONDON.
DICK KERR SYSTEM.
AUTOMATIC CIRCUIT BREAKER
TYPE D FORM
CALIBRATOR
MAGNET ARMATURE
SPARK GUARD
MAGNET ARM

FIG. 2

from the accompanying illustrations, of which Fig. 1 shows an external view of the assembled circuit breaker, and Figs. 2 and 3 show the same circuit breaker with the cover plate removed. Fig. 3 illustrates the arrangement of the main pole piece, which provides the blowout field.

The base is of cast iron, as are the two pole pieces (one for the blowout field and the other for the armature) and the armature itself. There is only one coil in this type, which not only provides the field for the blowout chamber, but also the field for the armature of the trip gear. It will be noticed from Figs. 2 and 3 that the core of this coil is divided by a tapered slot, which is $\frac{7}{16}$ in. wide at the top, and disappears to nothing at the base. This slot divides the field produced by the coil into that required by the blowout chamber and the armature respectively.

It might appear that the magnetic short circuit action of the armature, when close up against the pole face, would cause a considerable decrease in the field of the blowout chamber and thus make its action ineffective. This, however, is not the case, as, for anything above 200 ampères, the iron is working at saturation. The blowout will, in fact, act equally well with the armature hard up and the circuit breaker tripped from another source.

The insulation used in both the blowout housing and the spool of the magnet coil is the result of long experience and research work. This insulation, which is non-combustible, non-hygroscopic, and of a high dielectric strength, is known as " Dickerlite," and is largely made up of asbestos wool mixed with a forming varnish used as a binder. The mixture is placed in highly polished steel dies, and heated under a pressure of 1,500 lbs. per sq. inch, until all inflammable gases and volatile ingredients are expelled. The dies are then allowed to cool, and the insulation is extracted ready for use. Where necessary, nuts are fixed in the dies and moulded in the Dickerlite, so that tapping is avoided, and a perfect hold is given to any screws. Five such nuts are moulded in the lower half of the blowout housing of this circuit breaker, three for fixing the top of the blowout housing and two for the main contact.

The insulator so produced is not machined, so that the hard smooth surface produced by

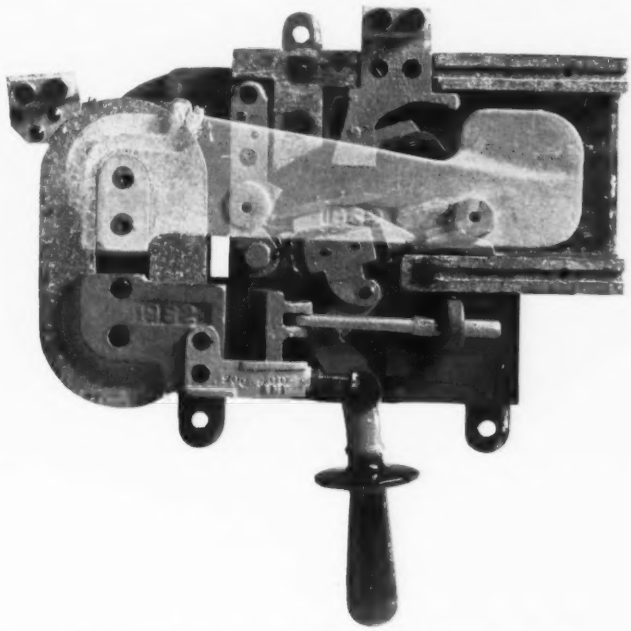


FIG. 3.—VIEW OF CIRCUIT BREAKER WITH COVER REMOVED, ILLUSTRATING POSITION OF MAIN POLE PIECE.

the polished die under pressure is not broken. There are three Dickerlite mouldings used in this circuit breaker, one for the magnet spool and the others for the blowout housing.

We give below the results of a series of tests carried out on this " Dicklerite " material :—

BREAKDOWN VOLTAGES.

Thickness.	Voltage.
$\frac{3}{16}$ in.	11,650 V.AC.
$\frac{1}{4}$ in.	14,000 V.AC.
$\frac{5}{16}$ in.	15,000 V.AC.
$\frac{1}{2}$ in.	19,000 V.AC.
$\frac{5}{8}$ in.	24,000 V.AC.

COMBUSTION TEST.

A sample of " Dickerlite " was subjected for a period of 15 seconds to a flame arc of 30 ampères on a 50 volt circuit, using carbon electrodes, and upon removal of the arc a small flame was visible for about one second. The sample was again placed in the arc for 30 seconds, and on removal was in no way charred, nor had the hard smooth surface been broken.

The only two soldered joints, one at either end of the coil, are also riveted, so that the complete circuit breaker is practically indestructible.

In the " on " position of the circuit breaker the toggle joint shown in Fig. 2 is just beyond dead centre. This keeps the main contacts together, and as the laminated contacts and the main circuit breaker spring are in compression, the lever on the handle of the switch exerts a force on the stop provided.

When the armature is drawn up, the tripping arm hits the toggle joint and carries it back over the dead centre, when the main-spring completes the opening of the circuit breaker.

The top arc-breaking contact is sprung, and the opening of these arcing contacts is delayed until the main contacts are opened, so that there is no danger of these contacts being damaged by arcing. Thus for a very short period of time the arcing contacts carry the main current. As soon as the arc is formed, it confines itself to the tips of the arcing contacts, and as the distance between these contacts increases and the length of the arc is increased, the arc itself actually moves round to the back of the contacts. The arc rapidly travels from the denser magnetic field towards the weaker field until it is finally ruptured by attenuation.

The distance between the armature and the pole face can be varied by means of a screw, which works against the back of the armature.

The tension of the spring which holds back the armature until the current reaches a definite value is also variable ; this is done by means of a nut and screw underneath the base of the circuit breaker.

The magnet coil consists of 16 turns of bare copper strip $\frac{13}{16}$ in. × ·072 in., wound on a former. The turns are insulated from each other by ·007 in. paper and shellac varnish. The coil is then slipped on to the spool (one end of which is removable) and the loose end replaced.

The following tests were carried out with the results shown :—

FOUR HOURS AT 100 AMPÈRES.

Time Mins.	Current. Amps.	Air Temp. °C.	Temp. Rise °C.		
			Magnet Coil.		Main Contact By Thermo-Couple.
			By Resistance.	By Thermo.	
0	100	13	0	0	—
30	100	13	24·3	32	—
60	100	13	43·6	42	—
90	100	13	53·5	49	16·5
120	100	13	53·5	53	—
150	100	13	63·0	55	—
180	100	14	63·0	58	23
210	100	14	63·0	59	—
240	102	14	65·0	61	26

AFTER SHUTTING DOWN—

Final temp. rise of Magnet Coil by Thermometer 61°C.
" " " " " " Resistance 65°C.
" " " Main Contact by Thermo-couple 26°C.

ONE HOUR AT 120 AMPÈRES.

Time Mins.	Current. Amps.	Air Temp. °C.	Temp. Rise °C.		
			Magnet Coil.		Main Contact. By Thermo-Couple.
			By Resistance.	By Thermo.	
0	120	12	0	0	0
15	120	12	28·6	30	—
30	120	12	47·5	38	12
40	120	12	55·2	49	—
50	120	12	62·5	55	16·5
60	120	12	71·5	64	21·5

AFTER SHUTTING DOWN—

Final temp. rise of Magnet Coil by Thermometer 64°C.
" " " " " " Resistance 71·5°C.
" " " Main Contact by Thermo-couple 21·5°C.

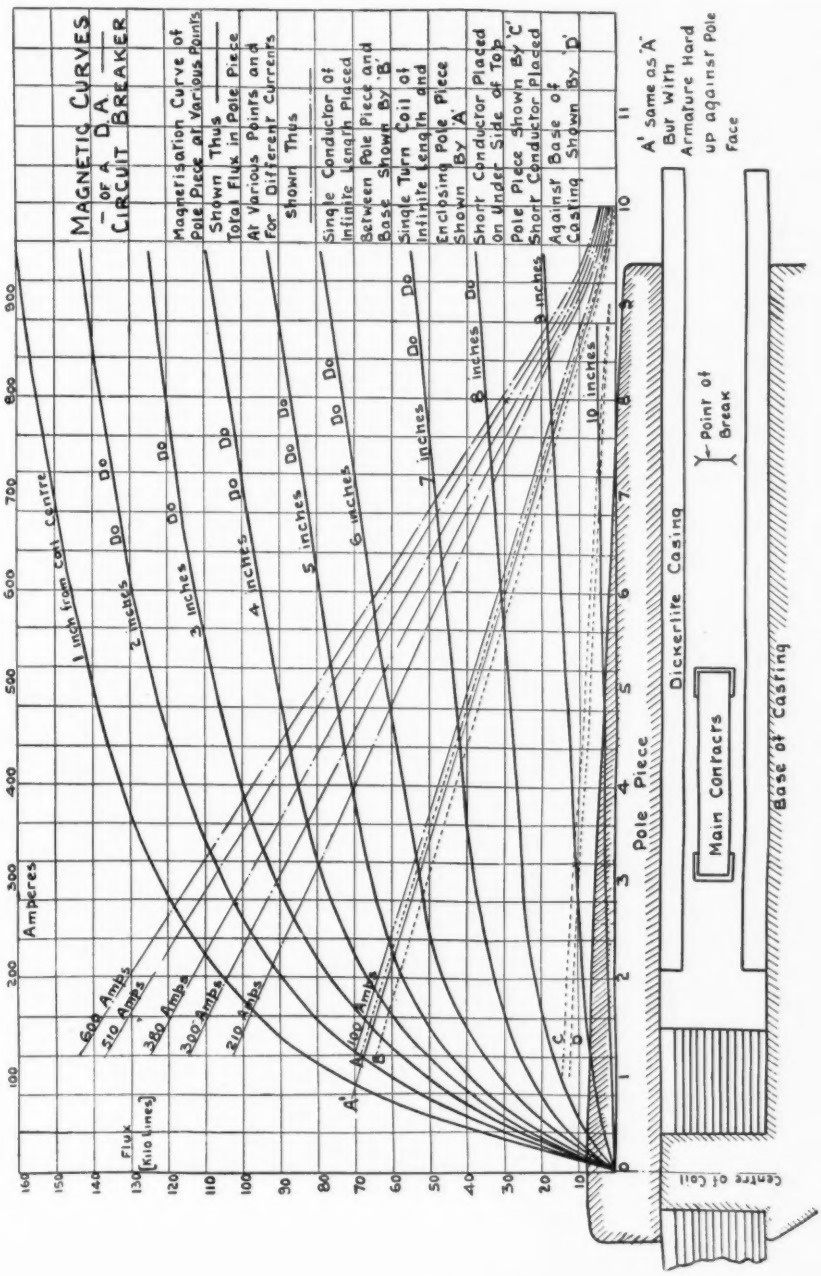

MAGNETIC CURVES
— OF A D.A. —
CIRCUIT BREAKER
Amperes
Flux (Kilo Lines)
1 inch from Cent. Centre
2 inches
3 inches
4 inches
5 inches
6 inches
7 inches
8 inches
9 inches
10 inches
Do
600 Amps
510 Amps
380 Amps
300 Amps
210 Amps
A 100 Amps
Magnetisation Curve of Pole Piece at Various Points Shown Thus ——
Total Flux in Pole Piece At Various Points and For Different Currents Shown Thus ——
Single Conductor of Infinite Length Placed Between Pole Piece and Base Shown By 'B'
Single Turn Coil of Infinite Length and Enclosing Pole Piece Shown By 'A'
Short Conductor Placed On Under Side of Top Pole Piece Shown By 'C'
Short Conductor Placed Against Base of Casting Shown By 'D'
A' Same as 'A' But With Armature Hard up against Pole Face
Pole Piece
Dickerlite Casing
Main Contacts
Point of Break
Base of Casting
Centre of Coil

Fig. 4.

FIVE MINUTES AT 250 AMPÈRES.

Time Mins.	Current Amps.	Air Temp. °C.	Temp. Rise °C.		
			Magnet Coil.		Main Contact. By Thermo-Couple.
			By Resistance.	By Thermo.	
0	235	13	—	—	—
1	250	13	13·8	17	—
2	250	13	29·6	25	—
3	247	13	36·4	29	—
4	248	13	47·3	36	—
5	246	13	54	42	10

After Shutting Down—

Final temp. rise of Magnet Coil by Thermometer 51°C.
" " " " " " Resistance 54°C.
" " " Main Contact by Thermo-couple 10°C.

FIVE MINUTES AT 300 AMPÈRES.

Time Mins.	Current. Amps.	Air Temp °C.	Temp. Rise °C.		
			Magnet Coil.		Main Contact. By Thermo-couple.
			By Resistance.	By Thermo.	
0	305	5	—	—	—
1	290	5	23·6	10	—
2	305	5	37·0	18	—
3	310	5	53·5	27	—
4	297	5	65·6	34	—
5	294	5	83·0	46	20

After Shutting Down—

Final temp. rise of Magnet Coil by Thermometer 58°C.
" " " " " " Resistance 83°C.
" " " Main Contact by Thermo-couple 20°C.

Magnetic Tests.

The following tests were made to ascertain the actual distribution of the magnetic fields, but owing to the complicated forms of the magnetic circuits, considerable difficulty was experienced in arriving at satisfactory results. The apparatus consisted of a search coil in conjunction with a calibrated ballistic galvanometer and from the deflections upon switching on the main current the results were tabulated and plotted, and are shown on the graph in Fig. 4.

In order to ascertain the total flux in the pole piece of the blowout coil, a search coil was made, consisting of four turns of wire wound on a leatheroid spool which passed easily over the main pole piece shown in Fig. 3. This pole had been marked off in inches from the centre of the magnetic coil, and the scale was continued for a distance of 0·6 ins. beyond the end of the pole, thus giving a total length of 10 ins. from the centre of the coil. Readings were taken at each inch marked, at currents of 100, 210, 300, 380, 510 and 600 ampères. The galvanometer deflections were reduced to kilo-lines, and were plotted as shown by the chain dotted lines in Fig. 4. From these curves the magnetization curves were plotted, showing the flux in the pole at certain distances from the centre of the coil, for certain values of the current in the coil. These curves are shown as full lines in Fig. 4.

To ascertain the field in the blowout chamber, a single conductor of " infinite " length, that is to say, one extending beyond the area of the field on either side of the pole piece, was used. This was arranged mid-way between the pole piece and the base of the circuit breaker. Readings were taken in similar positions to those in the previous tests, but with 100 ampères only in the main coil. The dotted curve B in Fig. 4 shows the values so obtained.

Another test was then carried out with 100 ampères in the main coil, using a search coil of a single turn. One side of this was placed between the pole and the base, and the other side passed over the pole piece. The result of this test is shown by the dotted curve A in Fig. 4.

Further tests were made with a coil of seven turns, the active length of which was just equal to the width of the pole piece, namely 1·14 ins. A current of 100 ampères was passed through the blow-out coil and two sets of readings were taken, one with the coil up against the pole, and the other with the coil laid upon the base, but in the same relative position as in the first case. The results of these two tests are shown by the dotted curves C and D respectively in Fig. 4.

Operation Tests.

The following tests were carried out to determine how many breaks the circuit breaker would endure before its action became ineffective. After more than 350 breaks had taken place under the most severe conditions without changing the arc breaking contacts, it was not considered worth while to continue the tests further.

A circuit breaker was mounted on the under side of a wooden board in a similar manner to that in which it would be mounted on the canopy of a tramcar. A sheet of iron was also mounted 9 ins. from the blowout housing and connected to that side of the 500 V. mains which would produce, in the event of the arc reaching the iron sheet, a short circuit on the 500 V. mains. Fig. 5 shows the arrangement

and a diagram of connections. In the first series of tests the fields of the two motors were connected in series. The resistance of each field was ·238 ohms, and of the breaker ·0025 ohms. The circuit breaker was set to operate at 200 amps., and by means of an automatic switch the circuit was closed with various values of resistance in series with the fields of the motors, *viz.*: 1·0, 0·6, 0·3 and 0·1 ohms. The circuit breaker operated perfectly in every case, and the contacts sustained no damage. Further tests were made with the circuit breaker set to operate at 400 ampères under similar conditions. In these tests a piece of paper was placed against the sheet of iron and became ignited, but the arc did not hang on to the sheet itself.

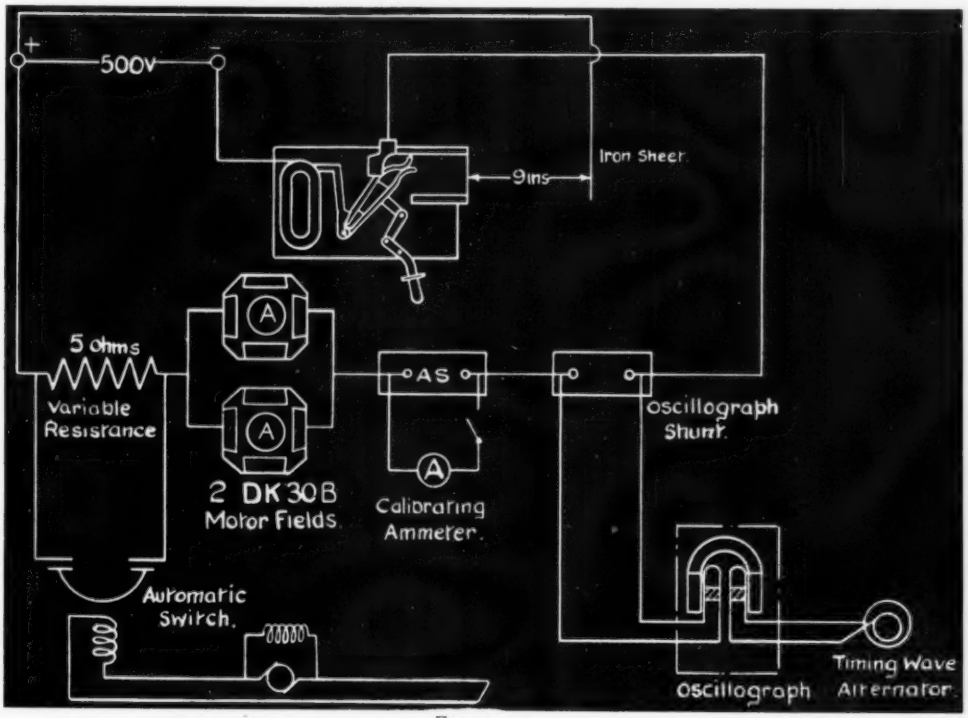


FIG. 5.

The fields were then cut out, and a resistance of 0·1 ohm only used. The circuit breaker was then set to open at 200 amps., and finally at 400 amps. The contacts did not suffer any damage, but there was a much louder report from the circuit breaker, indicating that the current had increased considerably, but as the paper on the iron sheet did not ignite, the arc must have been shorter. A series of rapid short circuits was then made with the field coils reconnected and the resistance set at 0·1 ohm. The circuit breaker was blown at the rate of fifteen times per minute. At the tenth break the housing began to flame slightly, but died out at once until the twentieth break. It then continued to flame during the succeeding twenty times when the circuit was broken. The flame died out soon after the trial was completed. In all these tests the breaker was most effective, even when the flame existed, and this appeared to have no detrimental effect on the efficient action of the blowout. A further series was then made with one set of field coils in circuit and the variable resistance at 0·1 ohms. Fifty breaks were made at the rate of twenty breaks per minute. The housing caught fire at the

thirtieth break and continued to flame until the remaining twenty breaks had been completed, after which the flame died away in thirty seconds. The arc was not so severe as when the two sets of coils were used; this was probably due to the fact that the inductance had been reduced by approximately one-half. (The inductance of the motor field used was ·0534 Henry).

Two sets of fields were then connected in parallel and the resistance cut out. The total resistance would then be about 0·12 ohm. Forty breaks were then made. The housing commenced to flame at the twenty-fifth break and continued until the thirtieth, when a pause of one minute was made to allow the flame to die out. It commenced to flame again at the thirty-second break, and continued until the fortieth, after which it disappeared in two minutes. This was the most severe of all the tests.

Upon examination after these tests the main contacts were quite untouched, but the arcing contacts were burned slightly on the back.

The " Dickerlite " housing was little affected, except along the top and bottom corners, which had become scored by the passage of the arc.

Duration of Arc—Oscillograms.

The method of measuring the actual duration of the arc was as follows:—The apparatus consisted of a disc of lamination steel in which were cut two small rectangular holes, $\frac{1}{8}'' \times 1''$, one at a distance of 4″ from the centre and the other $4\frac{1}{2}''$ from the centre and diametrically opposite the first. These holes were covered by thin oiled paper so that they were translucent. The disc was screwed to a wooden pulley and the whole mounted on a shaft in front of the blowout chamber of the circuit breaker. A camera was used to photograph the light passing through the holes in the disc, and, in order to prevent any other light from entering the camera, two large sheets of leatheroid, in which had been cut circular holes of a smaller diameter than the disc itself, were mounted on either side of the disc. The disc was then rotated by a small motor and its actual speed measured by means of a vibrometer; the variety of record obtained is illustrated in Fig. 6.

Fig. 6.

From the oscillograph and the arc recording apparatus just described, quantitative results of an interesting character were obtained. The following table summarizes good average results corresponding to the oscillograms reproduced in Fig. 7.

Load in series with Circuit Breaker.	Total Resistance. Ohms.	Total Inductance. Henries.	Maximum rise of Current. Amps.	Time of Circuit Breaker opening. Sec.	Current when the Circuit Breaker opens. Amps.	Time of rise to Maximum Current. Sec.	Duration of the Arc in Breaker. Sec.	Time of Current Decrease. Sec.	Rate of Increase of Current. Amps./Sec.
One Field ...	·240	·0534	1200	·043	1000	·06	·031	·040	20,000
Two Fields in parallel...	·121	·0267	1950	·027	1600	·05	·027	·029	39,000
Two Fields in series ...	·478	·1068	1000	·067	900	·09	·037	·042	11,500
Short Circuit	·003	·0001	2400	·047	2250	·05	·016	·087	48,000

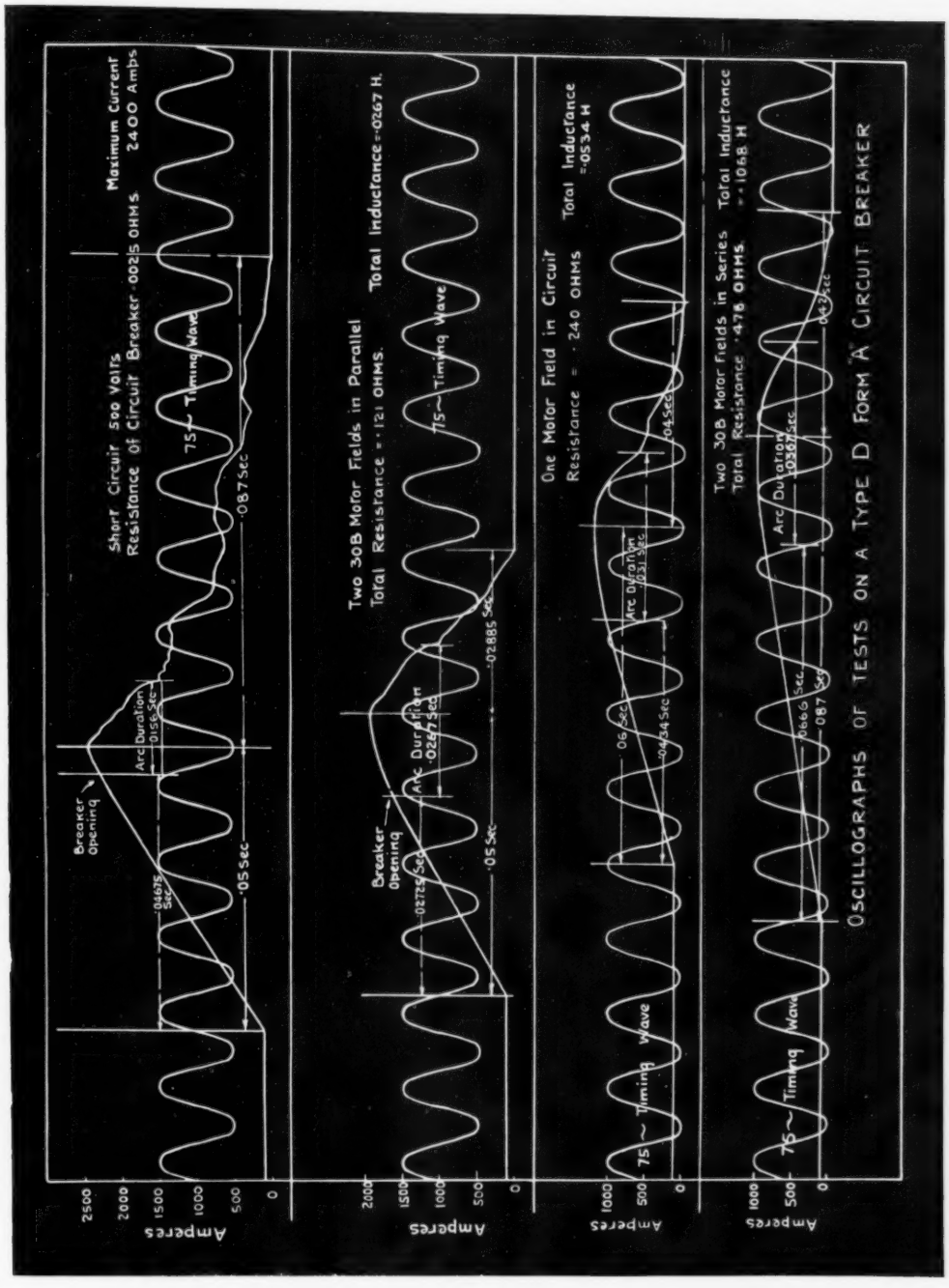

Short Circuit 500 Volts
Resistance of Circuit Breaker .002 OHMS
Maximum Current 2400 Amps
Breaker Opening
Arc Duration .0156 Sec
.0467 Sec
.055 sec
.087 Sec
75~ Timing Wave
Amperes
2500
2000
1500
1000
500
0
Two 30B Motor Fields in Parallel
Total Resistance = .121 OHMS.
Total Inductance = .0267 H.
Breaker Opening
.0272 Sec
Arc Duration .0273 Sec
.05 Sec
.02885 Sec
75~ Timing Wave
Amperes
2000
1500
1000
500
0
One Motor Field in Circuit
Resistance = .240 OHMS
Total Inductance = .0534 H
.06 Sec
Arc Duration .0231 Sec
.0434 Sec
.04 Sec
75~ Timing Wave
Amperes
1000
500
0
Two 30B Motor Fields in Series
Total Resistance = .478 OHMS.
Total Inductance = .1068 H
Arc Duration .0367 Sec
.0666 Sec
.087 Sec
.08 Sec
75~ Timing Wave
Amperes
1000
500
0
OSCILLOGRAPHS OF TESTS ON A TYPE D FORM A CIRCUIT BREAKER

FIG. 7.

The D.K. 34 Motor

A Light Weight Ventilated Tramway Motor for small Diameter Car Wheels.

[It is our intention to describe in the Journal from time to time special products of The English Electric Company, and, in particular, machines and apparatus of new or revised design. In the following pages will be found a description of the D.K. 34 Ventilated Tramway Motor.—EDITOR.]

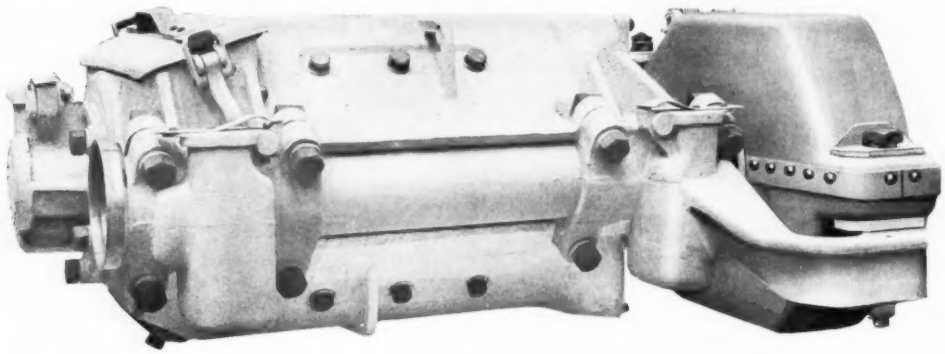


FIG. 1.

The English Electric Company have recently placed on the market another model of their special type of ventilated traction motor. It is known as the D.K. 34 Motor, and is specially designed for use with tram-cars with wheels of small diameter, *i.e.*, a diameter of 24 inch to 27 inch. These motors may be used on track gauges of 4 ft. (1·22 metres) and upwards, but if they are employed on a minimum track gauge of 4 ft. the car wheels are specially arranged to suit the motors.

This motor with the Type A winding is known as the D.K. 34A and has a one hour rating at the different voltages of :—

Voltage	500	550	600
H.P.	30	33	37

This motor may be provided with another winding to give a one hour rating at 500 volts of 40 H.P.

It will be seen from the illustrations, Figs. 1 to 5, that the motor is of the box frame type, suitable for mounting directly on to the tram-car axle, the other side of the motor being supported from the cross suspension bar of the car by means of two lugs cast on the magnet frame.

The axle bearing bushes are split and made of anti-friction bronze with machined grooves for distributing the oil. The thickness of the bushes is sufficient to allow for re-lining with white metal when renewal becomes necessary. They are keyed in cast steel boxes, bolted at an angle of about 60° to machined registered surfaces on the magnet frame, and are designed for a maximum axle diameter of 4 inches (102 mm.). The lubrication of these bearings is by means of wool waste and horsehair saturated in oil in direct contact with the axle for practically one-third of its diameter on the low pressure side. The oil reservoir is of sufficient capacity for several weeks' running. A dust cover is fitted round the axle between the motor axle bearings.

The power is transmitted to the axle through single reduction gearing. The pinion is of special high grade steel cut from the solid, keyed to a tapered armature shaft, and held in position by a steel nut securely locked. The gear wheel is also of special high grade steel and is made of the solid type only. The teeth are accurately cut and have a face width of 4½ inches (115 mm.). The standard gear ratio

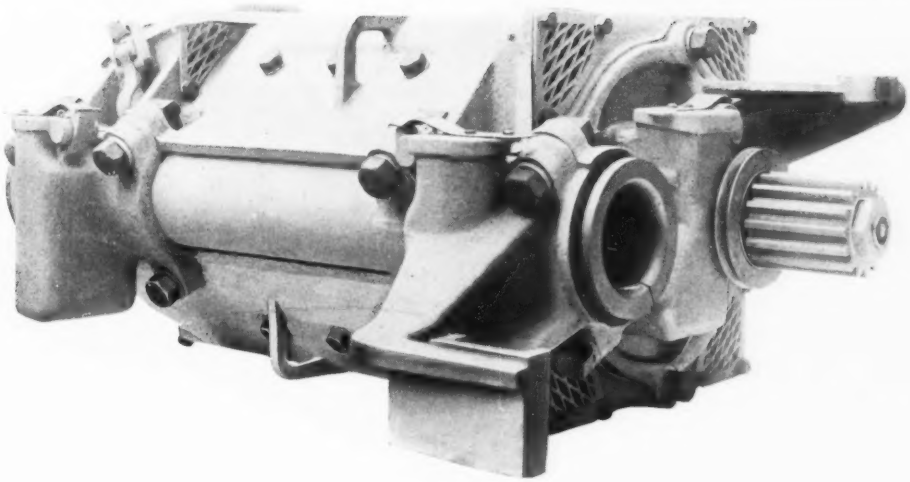


FIG. 2.

is 15 teeth in pinion and 67 teeth in gear wheel, although where required a different ratio may, within certain limits, be provided.

The gearing is enclosed in a pressed steel case in two parts, clamped together with steel bolts securely locked. Each part is pressed from a solid sheet 3/16 inch (4·7 mm.) thick. The case is supported at each end directly under the flanged lugs and therefore no riveted brackets are required. The cast-steel arms forming the supports are designed to withstand heavy vibration, and the case is clamped to them by steel bolts.

The magnet frame itself is of high permeability cast steel, and is made in the box frame type only. It is provided with bored and recessed openings at each end to receive the armature bearing boxes, which are secured by steel bolts tapped into the frame and securely locked against turning. Suitable machined seatings are provided for the four main and four interpoles, and also for the brush holder yoke. A large opening with pressed steel cover is arranged over the commutator and brush gear for easy inspection and adjustment. The cover is held in position by means of a spring lock, and is easily removable. Directly underneath the commutator is situated a hand-hole with a cover. Suitable openings fitted with perforated metal or gauze covers are provided for

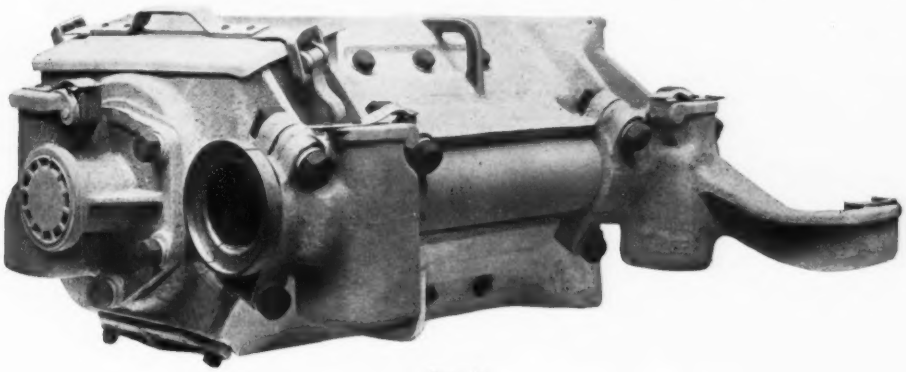


FIG. 3.

ventilation, the inlets being behind the opening over the commutator, while the exhaust openings are at the pinion end of the frame.

A special feature of this type of motor is the system of positive ventilation. Large axial ventilating ducts are provided in the armature core, extending through the commutator hub at one end, and leading to a powerful exhaust fan at the pinion end of the armature. The fan itself forms part of the armature end plate. The air enters through screened inlets at the commutator end ; one current of air is drawn through ducts in the armature core, and another current passes over the armature and around the field coils, both paths meeting at the fan, which discharges through four screened outlets at the pinion end. The volume of air and its velocity are such that any dust entering the casing is carried right through and expelled, this operation being facilitated by the smooth and direct air passages and by the unidirectional character of the air currents in the casing.

On a shop test at the rated voltage, at the end of a one-hour's continuous run with full load, through gearing, the temperature rise will not exceed 75° C. (135° F.), measured by thermometer, above a surrounding air temperature not exceeding 25° C. (77° F.). In this connection it is important to note that, due to the positive ventilation, the continuous capacity on a shop test with the same temperature rise is about 75 per cent. of the one-hour rated capacity, 40 per cent. being a comparable figure for the unventilated type of motor. The above ratings for the ventilated motor are with perforated covers over all the ventilating openings.

If, for special reasons, such as the fear of water entering the motor, due to flooded track, etc., it is considered desirable to close the bottom ventilating openings by solid metal plates instead of perforated covers, the continuous output of the motor on a shop test for the temperature rise specified above will be reduced to approximately 65 per cent. of the one-hour rating. In the event of *all* ventilating openings being closed by solid covers, the continuous output under similar conditions will be still further reduced to about 50 per cent. of the one-hour rating. It is not usually found necessary to fit solid covers to the lower ventilating openings, but it has been done in a few cases ; the necessity for fitting solid covers to all the openings never arises, unless some very severe and peculiar conditions of service have to be met.

The motors will run in either direction from no-load to 100 per cent. overload current, with fixed brush positions, practically without sparking.

The armature core is built up of thin steel laminations of a low hysteresis loss, each sheet being thinly coated with insulating lacquer. Slots are stamped in the laminations before assembly, to receive the armature coils. Large axial ventilating ducts are left to allow a free passage of air through the core. The core is carried on, and keyed to, the shaft, and is held in position by a cast steel endplate and steel nuts securely locked. As no radial ducts are required, spacing supports are eliminated and laminations can be clamped together under very great pressure, thus ensuring a tight core. The back endplate, which is pressed and keyed on to the shaft, supports the armature winding at the pinion end, and forms a powerful exhaust fan. The shaft is made of best quality forged steel, ground to gauge. The journal surfaces are rolled to ensure the maximum life of the bearing bushes.

The armature coils are machine wound, the wire being double cotton and asbestos covered. They are twice dipped in special varnish and baked between the dippings. Those portions of the coils which lie in the slots are insulated with mica, parchment paper and cambric tape, then vacuum dried and baked for twelve hours under vacuum. The coils are then placed in the slots, which are lined with leatheroid to prevent mechanical injury, the core being first sprayed with air-drying black varnish. Binding wires of steel, sunk flush with the core and insulated from the coils with hard wood strips, hold the windings in place. The end windings are supported by the back endplate and clamping plate, thereby completely shrouding the windings on the under-side. After the binding wires are in place, the whole armature is baked for twelve hours, and given a final spraying of air-drying black finishing varnish.

The armature bearings consist of solid bushes made of special anti-friction bronze with grooves machined to distribute the oil on the surface of the journal. The thickness of the bushes is sufficient to allow for re-lining with white metal when renewal becomes necessary and the bushes are securely keyed in position in the cast-steel bearing boxes. As in the case of the axle bearings, the lubrication is by means of wool

waste and horsehair saturated in oil, in direct contact with the shaft for practically one-third of its diameter on the low pressure side. The oil reservoir is of sufficient capacity for several weeks' running, and in order to prevent the oil from creeping along the shaft into the motor suitable oil throwers are provided.

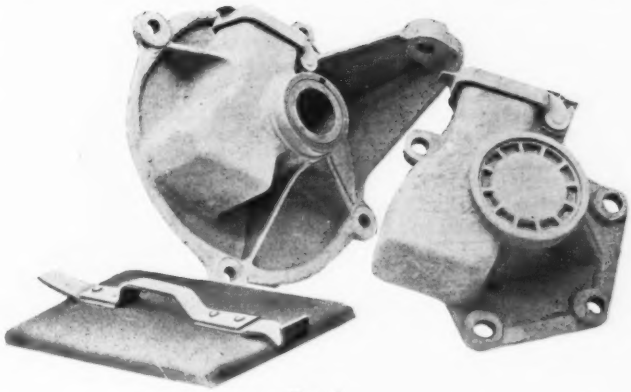


FIG. 4.

The commutator is built on a separate cast-steel spider, keyed to the shaft and held in position by a steel nut shrunk on the shaft. The bars of hard drawn copper, finished accurately to gauge, are insulated from each other with best grade mica, and held in position by heavy end flanges, fitting into deep "V" notches turned in the bars. The end flanges are insulated from the bars by micanite end rings and clamped together by a steel nut at the front end, enabling any bar to be taken out without dismantling the commutator. The mica between the bars is cut away to a depth of 3/64 inch (1·2 mm.) below the surface of the commutator, and this depth of groove should be maintained as the commutator wears down. An allowance of $\frac{1}{2}$ inch (12·7 mm.) is made for radial wear.

The main poles are built up of thin steel sheets riveted together between cast-steel end-plates and shaped to form a shoe to give a proper field distribution and at the same time serve as a support for the field coils.

The interpoles are made of drop forged steel with shaped pole tips for supporting the coils. Both main and interpoles are accurately machined and clamped to turned seatings on the magnet frame by steel bolts.

The main coils, as well as the interpole coils, are made from copper wire of square section, double cotton and asbestos covered; they are machine wound upon formers, being subsequently impregnated in a vacuum with insulating compound in order to fill all the interstices. They are then baked and afterwards insulated with a combined covering of mica and paper taped over with strong braided webbing. The complete coil is finally treated with special

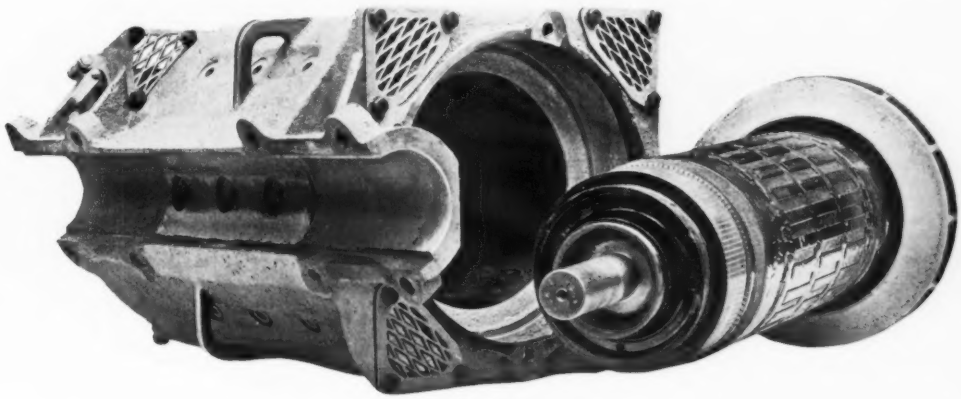


FIG. 5.

compound and again baked to render it impervious to moisture. Each coil is clamped between a pressed steel spring, bearing against the machined seating on the magnet frame and a brass washer supported by the pole shoe. Any shrinkage of the coil is thus taken up automatically and a rigid construction assured, failures from loose coils being entirely obviated.

The brush holders are made of cast bronze. They are adjustable radially and are clamped to an insulated yoke with securely locked steel bolts, which are accessible by removing the commutator cover.

The brushes are of carbon, provided with flexible copper connections, and slide in accurately finished boxes. Each brush is independently adjustable.

The insulation between field coils and magnet frame, and between armature windings and armature core is tested at 2,500 volts alternating current for one minute.

All parts of the motor are machined and finished to gauge and all drilling is done with special jigs, ensuring absolute interchangeability of all similar parts.

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